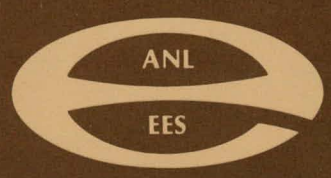
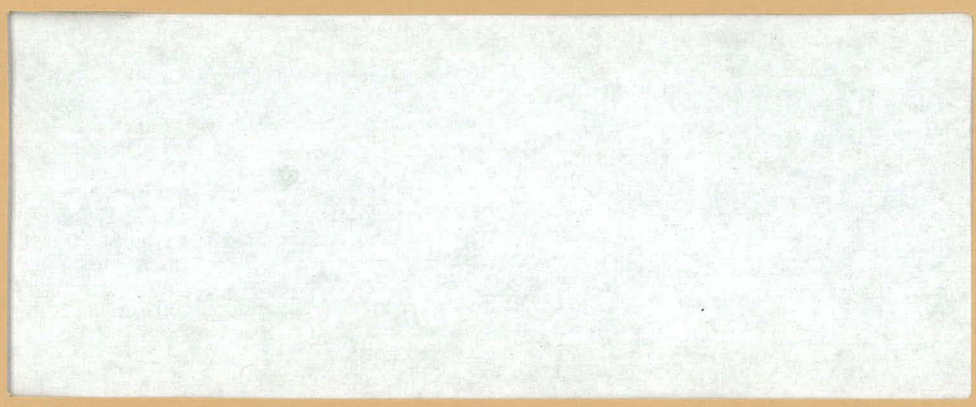


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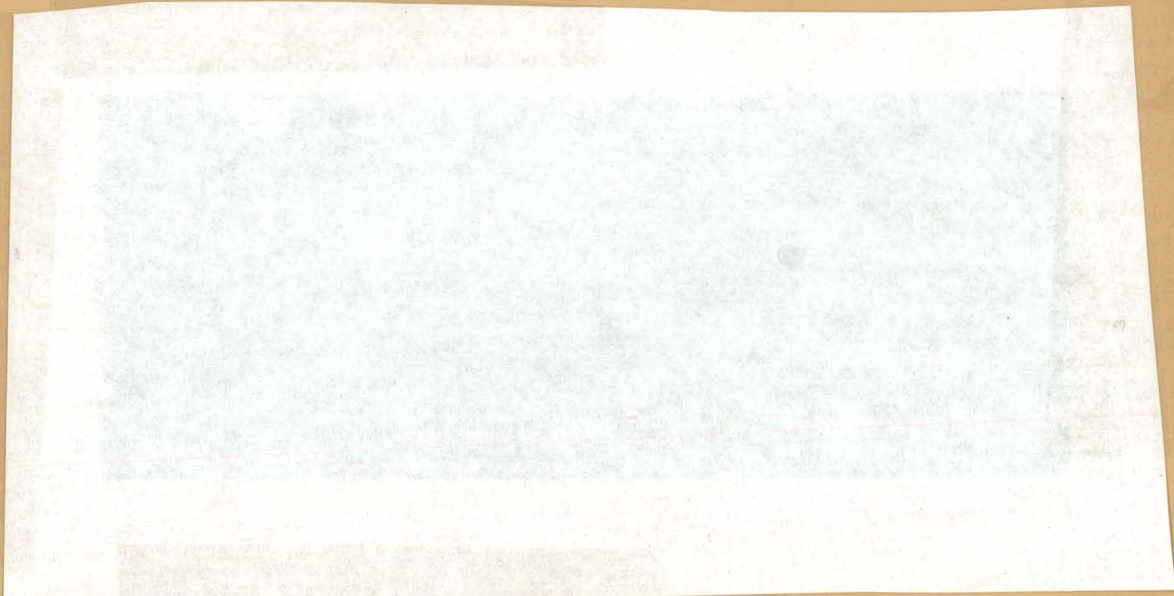
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This informal report presents preliminary results of ongoing work or work that is more limited in scope and depth than that described in formal reports issued by the Energy and Environmental Systems Division.

ARGONNE NATIONAL LABORATORY
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BARRIERS TO THE ADOPTION OF ENERGY-CONSERVING
TECHNOLOGIES IN THE TEXTILE INDUSTRY

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by

A.R. Evans and S.K. Zussman

Energy and Environmental Systems Division
Integrated Assessments and Policy Evaluations Group

September 1979

work sponsored by

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FOREWORD

The purpose of this work is to assemble a variety of existing data on the major prospects for and problems of implementing energy conservation technologies in the textile industry. This industry was chosen for study because it represents major opportunities for conservation, has strong regional economic impacts, and has been the subject of previous ANL-sponsored work not yet widely published. The report is intended primarily for those in governmental agencies interested in the implementation of energy conservation in the textile industry, although it may also provide a useful compilation for those in the industry. To the extent that some of the barriers to implementation and the means of overcoming them apply to other industries as well, the results presented here may be of broader interest; however, our conclusions should not be generalized beyond the particular industrial conditions for which they were derived.

The views expressed in this report do not represent official positions of Argonne National Laboratory or the U.S. Department of Energy. The mention of a proprietary product, process, or service does not imply its approval, and failure to mention it does not imply disapproval.

The principal author of this report is S.K. Zussman, Technical Communications Services, Downers Grove, Illinois.* This work provided a partial foundation for the award of a B.A. degree from Northeastern Illinois University in December 1979.

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EXECUTIVE SUMMARY

The textile industry is the tenth most energy-consuming industry in the United States, having used the energy equivalent of approximately 58 million barrels of oil in 1976. As in other industries, some energy is being conserved by "good housekeeping" measures, but further energy conservation will require the use of new energy-conserving technologies. This report characterizes the textile industry, identifies barriers to the adoption of energy-conserving technologies, and suggests possible measures to overcome those barriers. A summary of the findings of this report is presented in Table S.1.

Characterization of the Industry

The textile industry is centered in the Southeast, primarily in the states of North Carolina, South Carolina, and Georgia, and consists of both large, fully-integrated companies and small, single-operation plants; many are the primary employers in their communities. Facilities are scattered, and many of the plants are those built during the development of the industry in the early 1900s. The industry is labor-intensive; about 87% of the employed labor force consists of production workers, compared with 72% in all manufacturing. Generally, plant operations are managed by the production and engineering personnel at each plant, and corporate management tends to emphasize marketing and finance. With the rising costs of energy, energy management systems appear to be increasing in both large and small firms. Capital expenditures in the textile industry are higher than in other industries (65% in 1976, compared with a 41% all-manufacturing average). Historically, the industry has operated with a profit margin substantially lower than that of other manufacturing industries. A more detailed economic profile of the textile industry is contained in Sec. 2.2.

Energy Use

The textile industry is dependent upon natural gas as a source of energy for dyeing and finishing fabrics. Other operations (weaving, cutting, sewing) require electricity as the primary energy source. Until recently, these energy sources were low in cost; however, with deregulation or the need to obtain new gas supplies, the cost could be considerable. Fuel oil (at a substantially higher cost) is being increasingly substituted in steam-raising operations. Section 2.3.1 is a description of energy use in the Southeast (North and South Carolina and Georgia); a general process description of textile manufacturing is presented in Sec. 2.3.2.

In response to the energy efficiency targets set by the Federal Energy Administration, the textile industry increased energy efficiency in 1976 by 8.9% over 1972, and an estimated 9.2% in the first half of 1977.

Table S.1 Summary of Findings

INDUSTRY PROFILE

- Centered in Southeast (North and South Carolina, Georgia).
- Labor-intensive.
- Low profit margin.
- High rate of capital expenditure.
- Facilities scattered, with a few areas of high concentration (Dolton, Ga.; High Pt. - Greensboro - Winston-Salem, N.C.); some large, integrated companies and some small, single-operation plants.
- Many facilities built during early 1900s; over 74% of equipment more than 10 years old.

ENERGY USE

- Dependent mainly upon natural gas for dyeing and finishing; other operations use electricity.
- Fuel oil used as substitute in steam generation.
- Increased energy efficiency in 1976 by 8.9% over 1972.

BARRIERS IDENTIFIED

- Primary barrier is economics -- lack of discretionary capital. Large companies use return-on-investment criterion (25-38%) and small companies use payback period (2-5 yrs) criterion. Some economists/energy managers are beginning to include special considerations for evaluating energy conservation expenditures; however, most companies now do not evaluate energy conservation expenditures differently from other expenditures.
- Product quality and production rate are primary concerns.
- Commitment of capital for compliance is seen as a barrier to investment.
- Lack of technical expertise and information.
- Insufficient tax incentives.

POSSIBLE MEASURES TO ELIMINATE BARRIERS

- Economic incentives.
 - Increase in fossil fuel prices.
 - Sponsor basic research and in-plant demonstrations; sponsor research into effective methods of market penetration for new technologies; sponsor followup meetings to provide outside assistance to companies for implementation of energy conserving technologies.
 - Develop regional approach to energy conservation..
-

Barriers to the Implementation of Energy-Conserving Technologies

The primary barrier to the implementation of energy-conserving technologies in the textile industry is economics -- a sufficiently short payback period or sufficiently great return on investment must be achieved to justify energy conservation expenditures. The payback criterion is used by most small companies, with a period of from 2 to 5 years considered acceptable. Large companies use the return-on-investment criterion almost exclusively, with a range of 25% to 38% considered acceptable. Some energy managers are beginning to include special considerations in their evaluations of energy conservation expenditures, but in most firms energy conservation expenditures are not evaluated differently from other expenditures.

A second barrier closely associated with the first is technical acceptability; any technology that slows production or alters product quality is not likely to be accepted by the textile industry. Because the industry operates on a low profit margin, a decrease in production can alter a company's profitability. The apparel industry is the primary customer for textiles, and since the apparel market changes rapidly and often, the textile industry must be able to meet its demand.

The third barrier to the implementation of energy-conserving technologies is conflict between commitments of capital for compliance with environmental and health regulations, and for investment in energy conservation measures. Uncertainty regarding regulatory standards not yet promulgated is also a hindrance. Industry is reluctant to invest in equipment that might need to be replaced or greatly modified to meet new health and environmental standards.

The fourth barrier identified in this study is lack of information and technical expertise. To maximize energy conservation, it is essential that industries have current information on energy-conserving technologies via workshops, research, demonstration projects, and the like. Lack of information can act as a barrier, particularly to small companies, which may lack the technical expertise to maximize their energy conservation potential.

The major sources of energy conservation information for the textile industry are trade organizations and journals. The American Textile Manufacturers Institute, in particular, is considered by textile companies to be a useful source of information through programs and meetings. A list of selected major textile industry journals, trade publications, and organizations and a brief description of each is included in this report as Appendix C.

This study drew heavily on the results of a survey of textile companies conducted by Lowry et al. (Ref. 2).

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1 INTRODUCTION

Energy has been conserved by "good housekeeping" measures in many industries. However, to further reduce energy consumption or, in some cases, to take advantage of an alternative fuel, these industries will need to implement new energy-conserving technologies. To do so will require the elimination or minimization of economic, technical, and regulatory barriers.

The textile industry was selected for this study for the following reasons:

- It is the tenth most energy-consumptive industry, having used the energy equivalent of approximately 58 million barrels of oil in 1976.*
- Energy conservation to date has been achieved primarily through "good housekeeping" measures.
- The industry consists of both large, integrated companies and small, single-operation plants.
- Corporate management generally is not involved in routine plant operations; plant operating personnel are in charge.
- Textile facilities are scattered, and many structures are old (constructed during the early 1900s), with modernized operations.
- Equipment is simple, and as a result more than 74% of the operating equipment is over 10 years old.

Although each industry has its own specific conditions and problems, many of the findings of this study are applicable to other industries with profiles similar to that of the textile industry.

This report contains an overview of the textile industry and a discussion of energy-conserving technologies currently available or at the pilot-demonstration stage. It identifies existing and potential barriers to the adoption of these technologies in the textile industry.

*1976 U.S. Survey of Manufactures (Ref. 1). The values used were for purchased fuels and electric energy and thus assume generating and transmission losses. They do not include electric energy generated less that sold.

2 CHARACTERIZATION OF THE TEXTILE INDUSTRY

The textile industry [Standard Industrial Classification (SIC) 22] consists of the manufacturers and finishers of yarn, cordage, woven and knit fabrics, and rugs and carpets. Its primary customer is the domestic apparel industry,* followed by the auto and furniture industries. Knit apparel, yarns, and carpets are also manufactured as final products for the consumer.

2.1 DEVELOPMENT AND STRUCTURE OF THE INDUSTRY

The textile industry originally centered in the New England states, but, during the early 1900s, shifted to the Southeast because of its abundance of water, inexpensive labor, and proximity to natural raw fibers. At that time most plants were individually owned and performed one specialized process.

Many plants currently in operation were constructed during the early 1900s. Major corporations have evolved by the acquisition of these facilities, so that the corporate structure of a large firm is a combination of several small ones and may include all the processes that occur within the industry. However, many textile firms are small, family-owned companies, and in many cases the primary employers in their towns;² thus, preservation of a textile plant may be critical to the socioeconomic stability of a community.

Because the textile industry consists of large, fully integrated companies and smaller independent ones that specialize in a particular operation, it is not dominated by any one firm; the sales of the largest are approximately 6% of total industry sales.³ Another result of this course of development is that corporate management usually has relatively little input into plant operations and tends to emphasize marketing and finance, whereas production and engineering are left to the operating personnel at each plant.

2.2 ECONOMIC OVERVIEW

After recovering from the effects of the severe energy shortages in the early part of 1977, the textile industry improved at a moderate rate for the rest of that year. Demand for apparel products, cars, housing, and furniture (the primary users of textile products) increased moderately in 1977, along with consumer spending. Production in the textile industry, as measured by the Federal Reserve Board's production index, increased throughout the first half of 1977 after declining in the second half of 1976. Shipments of textile mill products in the first half of 1977 were almost 10% greater than in 1976. Inventories averaged 8% less than in 1976. Capital expenditures for new plants and equipment were estimated at \$930

*The apparel industry (SIC 23) consists of firms that cut and sew clothing (knits and wovens, outerwear and underwear) from purchased fabric.

million in 1977, an increase of 11% over the previous year.* Employment in the textile industry was over one million for the first time since June 1974.⁴

The U.S. textile industry employs one out of every eight manufacturing workers. Broadwoven and knit fabric mills together employ more than half of the textile industry work force. The industry is concentrated in the Southeast; it is the primary employer in the Carolinas and Georgia,⁵ and is one of the primary employers in many communities in other states, as well.⁴

2.2.1 Sales and Profits

Textile industry profits totaled \$167 million on sale of \$8.3 billion in the first quarter of 1977, an increase of 26% in profits from the fourth quarter of 1976, but a decline of 34% from the first quarter of 1976. Textile profits in 1976 were \$811 million on sales of \$3.4 billion. While 1976 profits were almost double those of 1975, they were still short of the \$831 million recorded in 1973. Profits after taxes as a percent of stockholders' equity doubled in 1976 after declining 47% in 1975.⁴ Historically, profit margins in the textile industry have been substantially lower than the all-industry average.⁶ In good years, after-tax profits typically represent 3% or less of sales for all major textile producers. This trend is likely to continue. In fact, increasing labor and energy costs and the capital investment required to comply with recent environmental and health legislation may cause a further decrease in profit margin.

There were 72 bankruptcies involving \$177 million in liabilities in 1976; these were attributed to tightening credit and rising costs. Although this was a decrease of 28% from 1975, the total liabilities in 1976 increased by over 200% from those of 1975.

A financial profile of the textile industry is presented in Appendix A.

2.2.2 Capital Expenditures

Capital expenditures for new plant equipment in the textile industry were estimated at a record \$930 million in 1977, up 11% from 1976,⁷ and 7% more than the previous high of \$840 million recorded in 1974.⁴ Capital expenditures for the textile industry in 1976, compared to cash flow, were 65%, considerably higher than the all-manufacturing average of 41%.⁸ Expenditures for new plants and equipment in 1975 and 1976 are shown in Table 2.1. Estimated capital expenditures for new plants and equipment in 1975 were \$660 million, down from \$840 million in 1974 and \$770 million in 1973.** About 5% of this investment was spent in 1973 and 1974 to meet air and water quality standards set by the Environmental Protection Agency (EPA) and the

*The 11% increase cited (Ref. 4) does not agree with data presented in Table 2.1; however, this probably is due to adjustment of data, and the trend indicated is probably correct.

**Data in Refs. 6 and 7 conflict; this is assumed to be due to adjustment in data.

Table 2.1 Expenditures for New Plants and New Equipment in the Textile Industry (SIC 22), 1975 and 1976 (\$10⁶)

SIC Code		Total New Expenditures		New Structures and Additions to Plants		New Machinery	
		1975	1976	1975	1976	1975	1976
22	Textile Mill Products	996.7	1087.4	222.0	163.3	774.8	924.1
2211	Weaving mills, cotton	133.4 ^a	124.3	24.0	15.4	109.4	108.9
2221	Weaving mills, man-made fiber	192.2	245.6	31.9	16.8	160.3	228.8
2231	Weaving, finishing mills, wool	10.9	41.7(76) ^b	2.0	12.5(77)	8.9	29.1(76)
2241	Narrow fabric mills	12.1 ^a	11.3(39)	2.2	2.2(51)	9.9	9.1(35)
225	Knitting mills	228.3	203.8	66.8	38.7	161.6	165.1
2251	Women's hosiery except socks	15.9	13.1	5.2	3.4(16)	10.6	9.7
2252	Hosiery, nec	9.9	14.5	2.2	3.6	7.7	10.9
2253	Knit outerwear mills	46.7	35.2	17.2	6.6(16)	29.5	28.6
2254	Knit underwear mills	19.3	9.7	12.6	1.1	6.6	8.6
2257	Circular knit fabric mills	94.2	87.1	19.3	17.2	74.9	69.9
2258	Warp knit fabric mills	33.6	420.0	6.2	6.3	27.4	35.7
2259	Knitting mills, nec	8.7 ^a	2.3(57)	4.0	0.5(72)	4.7	1.8(52)
226	Textile finishing, except wool	91.5	116.7(13)	19.5	20.0(22)	72.0	96.8
2261	Finishing plants, cotton	20.6	23.8(32)	3.6	2.5(90)	17.0	21.3(25)
2262	Finishing plants, man-made fiber	63.7	82.0(16)	14.2	15.1(25)	49.4	66.9
2269	Finishing plants, nec	7.3 ^a	11.0	1.7	2.3	5.6	8.6
227	Floor covering mills	52.6	60.4	14.6	9.8	38.0	50.6
2271	Woven carpets and rugs	3.1	4.8	0.3	0.5	2.8	4.3
2272	Tufted carpets and rugs	45.0	52.8	13.4	8.7	31.6	44.1
2279	Carpets and rugs, nec	4.5 ^a	2.7(49)	0.9	0.5(70)	3.6	2.2(43)
228	Yarn and thread mills	160.5	166.6	23.7	23.7	136.8	142.9
2281	Yarn mills, except wool	100.5 ^a	80.0	12.2	10.2(18)	88.3	69.9
2282	Throwing and winding mills	54.6	78.3	11.0	12.3(17)	43.5	66.0
2283	Wool yarn mills	1.6	3.1(16)	0.2	0.5(29)	1.4	2.5(17)
2284	Thread mills	3.9	5.2(38)	0.3	0.7	3.6	4.5(44)
229	Misc. textile goods	115.3	116.9	37.4	24.1	77.9	92.8
2291	Felt goods, except woven and hats	5.4 ^a	6.3(21)	0.7	2.1(39)	4.7	4.2(17)
2292	Lace goods	0.3	2.3(77)	0.3	0.4(81)	c	1.9(76)
2293	Paddings and upholstery filling	7.1	4.8(14)	5.4	1.1(22)	1.8	3.8
2294	Processed textile waste	1.2	3.7(21)	0.1	0.8(34)	1.1	2.9(19)
2295	Coated fabrics, not rubberized	34.5	25.8	9.2	3.6(17)	25.2	22.2
2296	Tire cord and fabric	7.7	6.0	2.4	0.6	5.3	5.4
2297	Nonwoven fabrics	33.9	41.0	7.3	8.1	32.9	26.6
2298	Cordage and twine	11.2	12.7	5.0	6.2(35)	6.3	6.4
2299	Textile goods, nec	13.9 ^b	14.4(28)	7.0	1.2(36)	6.9	13.2(29)

^aRevised.

^bSampling errors (the differences between the estimates obtained and the results theoretically obtainable from a comparable complete coverage survey) are unknown. However, guides to the potential size of the sampling errors are provided by estimates of errors. Any figure with an associated error exceeding 15% (given in parentheses) may be of limited reliability.

^cLess than \$50,000.

Source: Ref. 7.

Occupational Health and Safety Standards set by the Department of Labor. These investment costs are expected to continue over the next five to ten years, and will compete with the capital funds that can be assigned to new technological activity.⁶

With a view to improving productivity and efficiency, the textile industry is planning for capital investments that will provide new capacity, the maintenance of existing plants, and the installation of environmental control and energy conservation equipment.

2.2.3 Return on Investment

Return on investment (book value of equity) has been more stable in the textile industry in recent years, although generally depressed.⁹ The industry showed its greatest strength just prior to the 1975 recession with return on equity reaching 8.8% and 8.7% in 1974 and 1976, respectively (see Fig. 2.1). These returns are low compared to those of other energy-consuming industries. Return on assets in the textile industry is low at 4.3%. Return on sales (which is the least significant measure of earnings strength) is lower in the textile industry than in any of the other large energy-consuming industries. The plant and equipment base in the textile industry is more mature than in most industries (56% depreciated), yet capital expenditures were only 30% greater than depreciation expense. On an inflation-adjusted basis, this would indicate attrition in the effective

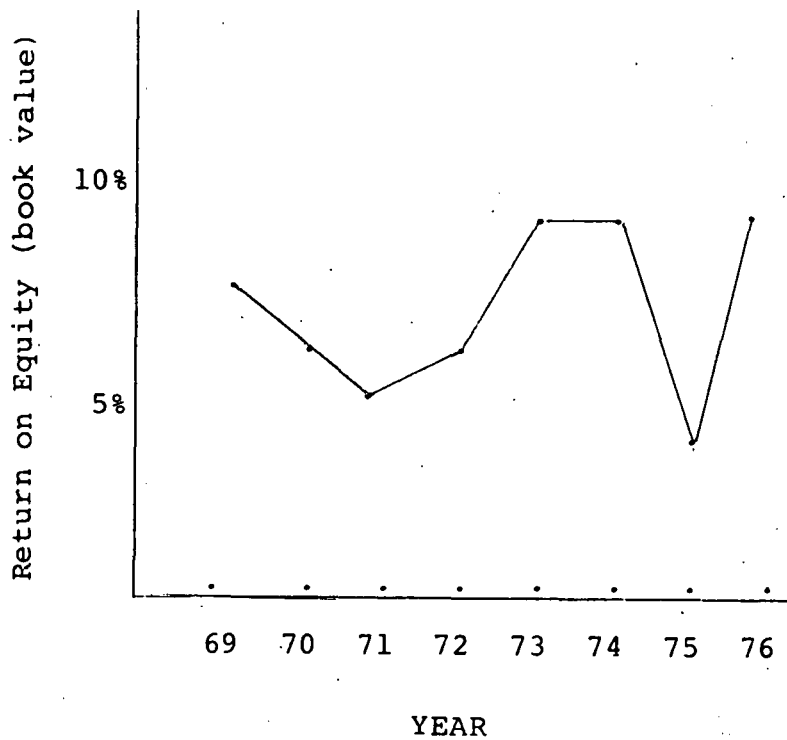


Fig. 2.1 Return on Investment in the Textile Industry
(Source: Ref. 9)

asset base of the industry. This is reflected in Fig. 2.2, which shows that with its average asset life of 17.9 years, the textile industry's capital expenditures were only 7.7% of its total capitalization, whereas 12% was the average for the energy-consuming industries represented in the figure.

The equity of the textile industry has the lowest market value/book ratio of the major energy-consuming industries (0.64).⁹ Such a low ratio is a real barrier to issuing new equity in the industry. Although the debt-to-capital ratio is very low, the interest coverage ratio does not indicate much capacity for new debt. Circumstances facing the textile industry may suggest that this 32% debt-to-capital ratio is actually higher than the investing community would like to see, indicating the need for the industry to reduce the ratio of debt in its capital structure even further.

Thus, all three primary sources of capital (retained earnings, new debt issues, new equity issues) are constrained. This suggests both limits to the amount of capital available for investment in energy-conserving technologies, and the possibility that what discretionary capital is available might be best spent toward diversification rather than cost-reduction investments.

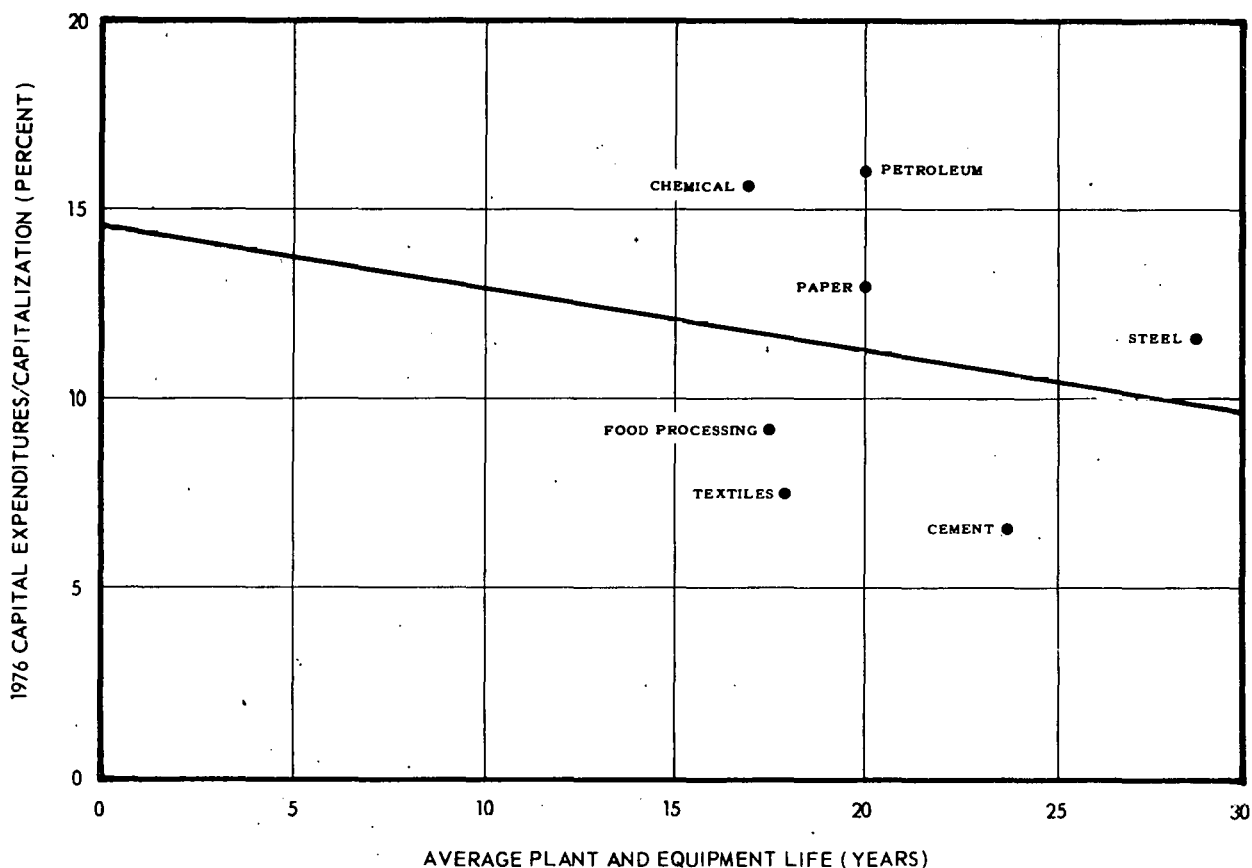


Fig. 2.2 Industry Capital Expenditures as a Function of Average Asset Life for Seven Energy-Consuming Industries
(Source: Ref. 9)

2.2.4 Energy Costs

Traditionally, energy costs have not been a major factor in the production of textile fabrics because natural gas, fuel oil, and electricity have been low in cost. With deregulation, or the need to obtain new gas supplies, the impact could be considerable. Natural gas is an essential fuel for certain textile operations (e.g., heat setting and drying) because the combustion products come in contact with the fabric. Fuel oil, at a substantially higher cost, is being increasingly substituted for natural gas in steam-raising operations.⁶

Actual energy costs vary widely with the type of fabric and the product mix, and, according to industry estimates, range from 2 to 8 cents per pound of fabric. Knit goods such as hosiery tend to be at the low end of the cost range, whereas heavy woven fabrics tend to be at the high end. However, geographic location and product mix can also cause large variations in energy cost.⁶

In 1976, 328.6×10^{12} Btu of purchased fuels and electric energy were consumed by the textile industry, at a cost of \$990.8 million -- a cost of \$3.01 per million Btu. This was an increase of 7% over 1975 in both quantity used and cost per million Btu. Quantities and costs of purchased fuels and electric energy used by the textile industry in 1976 are shown in Table 2.2.

2.3 ENERGY USE PATTERNS

The textile industry is highly dependent upon natural gas as a source of thermal energy, primarily for dyeing and finishing of textiles. Electricity is required for machine operations and for lighting and environmental conditioning (space heating and cooling and removal of cotton fibers from the air). Process diagrams of a typical knit-fabric mill, woven-fabric mill, and carpet mill are presented in Figs. 2.3 through 2.5, respectively.

Table 2.2 Quantities and Costs of Purchased Fuels and Electric Energy Used by the Textile Industry (SIC 22) in 1976

Fuel	Quantity Used	Cost (\$10 ⁶)
Natural gas	78.7×10^9 ft ³	113.1
Other fuels		30.0
Electricity	28×10^9 kWh	586.5
Generated less sold	483.7×10^6 kWh	125.4
Distillate fuel oil	4,964,600 bbl	68.1
Residual fuel oil	10,010,100 bbl	-
Coal	1,141,900 short tons	36.6

Source: Ref. 1.

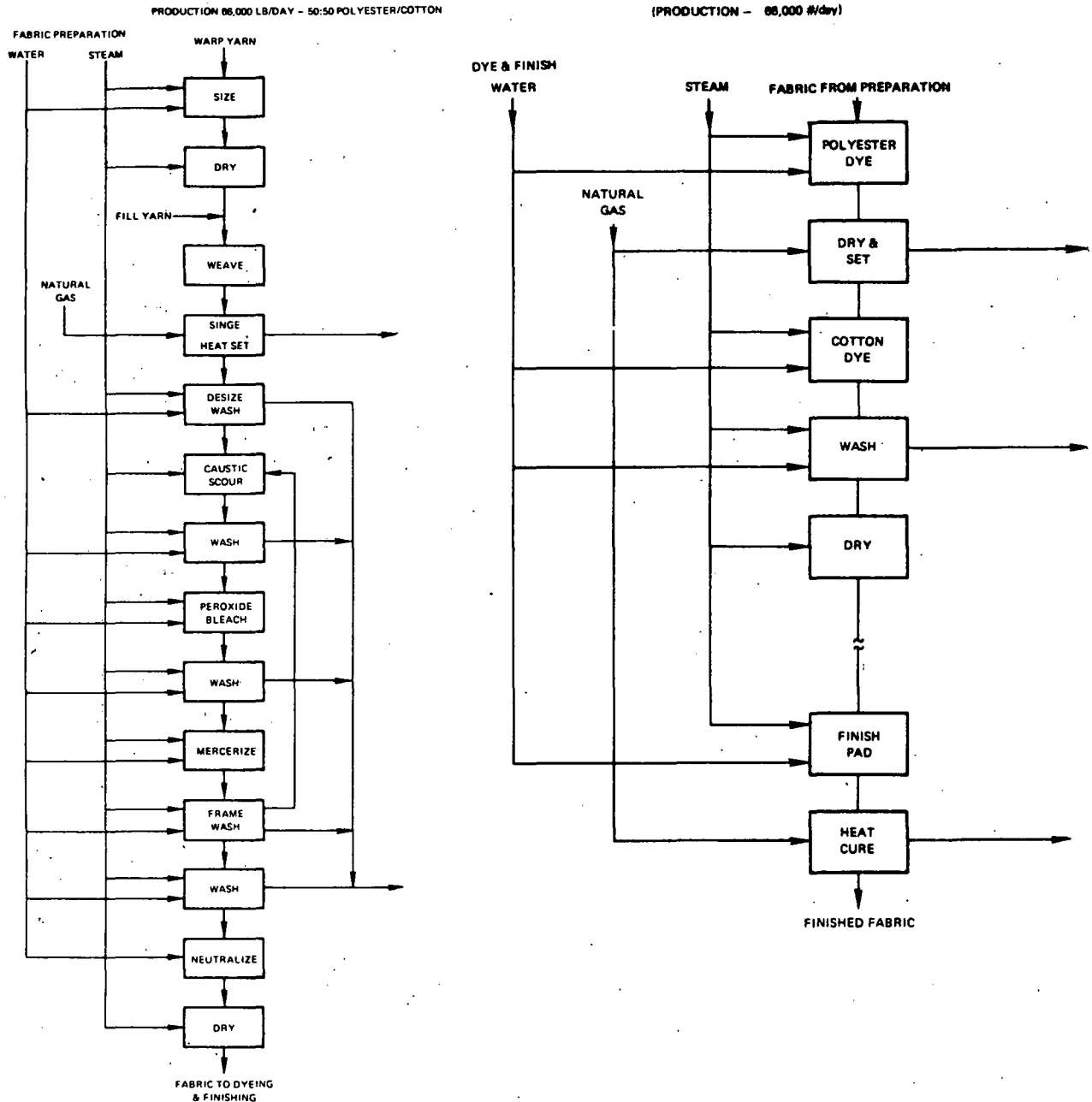


Fig. 2.4 Process Diagram of Typical Woven-Fabric Mill
(Source: Ref. 6)

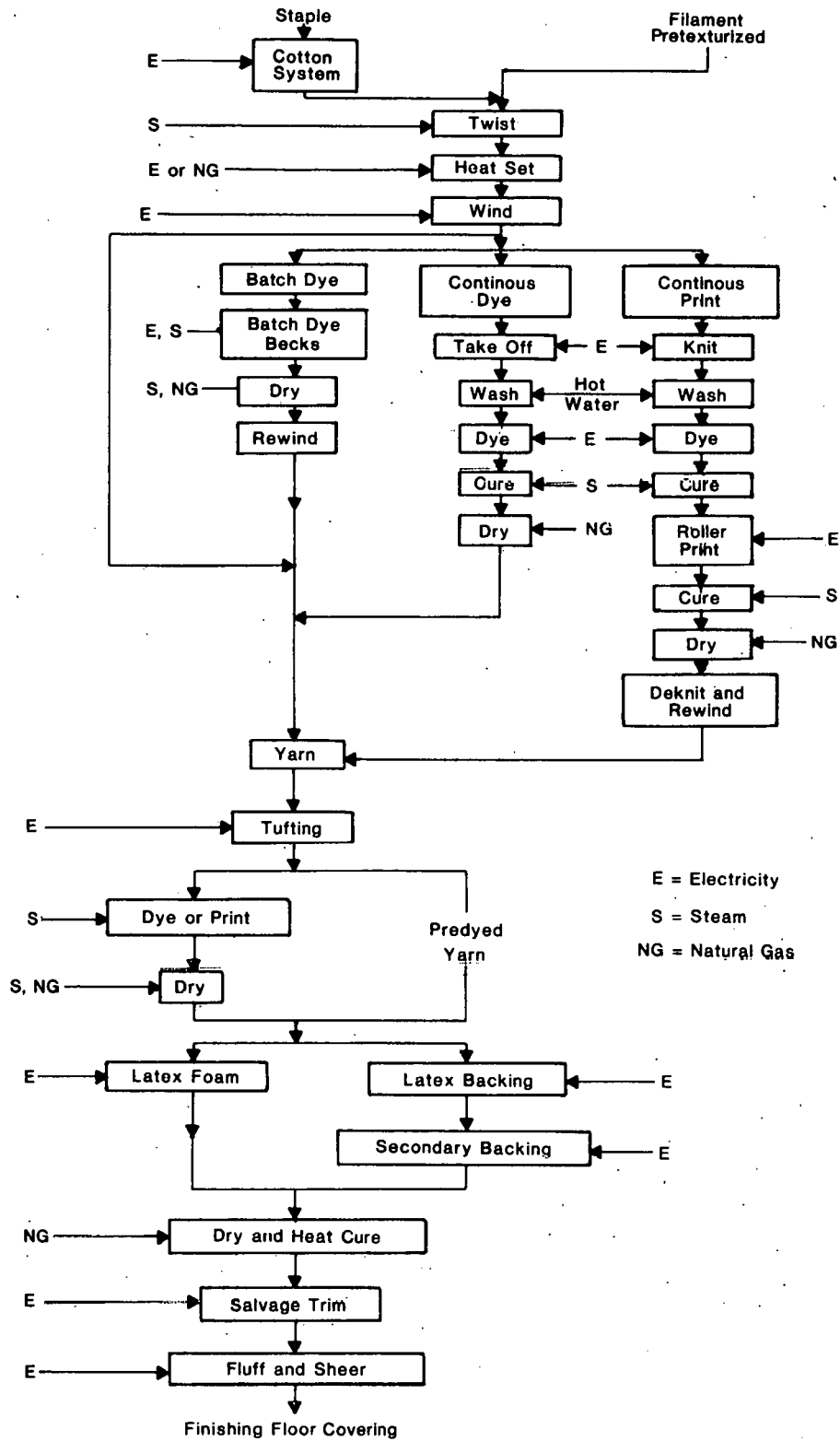


Fig. 2.5 Process Diagram of Typical Carpet Mill
 (Source: Ref. 10)

Additional fuels used by the textile industry include fuel oil and coal and, to a lesser extent, liquid propane gas (LPG), wood, and purchased steam. Liquid propane gas is used by many firms as standby fuel. Of the lesser-used fuels, wood seems to be receiving the most consideration as an alternative fuel. Many firms have considered the use of wood chips,³ and one textile firm is expected to increase its current 75% waste-wood fuel capacity to 100%.¹¹ Trends in energy use in the textile industry from 1962 to 1974 are shown in Table 2.3. Quantities and costs of purchased fuels and electric energy for 1975 and 1976 are shown by state in Table 2.4.

2.3.1 Regional Energy Use

The textile industry is concentrated in the Southeast, primarily in the states of North Carolina, South Carolina, and Georgia. As shown in Table 2.4, the state that uses the most fuels and electricity is North Carolina (88.4×10^{12} Btu in 1976), with South Carolina and Georgia second (64.9×10^{12}) and third (46.7×10^{12}), respectively. A breakdown of fuel quantities and costs is presented in Table 2.5. There is no single most energy-consuming textile industry component within these three states. Further, some components consume fuels directly, whereas others depend primarily on electric energy. The most fuel-consuming component of the textile industry in North Carolina is SIC 225, Knitting Mills, which in 1976 used 16.7×10^{12} Btu of purchased fuels. In the same state, the greatest user of electric energy in 1976 was SIC 228, Yarn and Thread Mills (3.72×10^9 kWh). The primary user of purchased fuels in South Carolina was SIC 226, Textile Finishing Except Wool, using 25.3×10^{12} Btu of energy. Electric energy in South Carolina was used primarily in SIC 222, Weaving Mills,

Table 2.3 Trends in Energy Use in the Textile Industry, 1962-1974

Fuel Type	Energy Consumption (as percent of total)				
	1962	1967	1971	1972	1974
Fuel oil	24	13	19	19	20
Coal	29	15	10	9	7
Natural gas	22	18	28	29	32
Other fuels and fuels not specified by kind	5	31	19	19	14
Total purchased fuel	80	78	77	76	72
Electricity	20	22	23	24	28
Total purchased fuel and electricity	100	100	100	100	100
Total purchased fuel and electricity (10^9 kWh)	74.1	93.0	106.5	139	94.6

Source: Ref. 12.

Table 2.4 Quantity and Cost of Purchased Fuels and Electric Energy Used by the Textile Industry (SIC 22) for Heat and Power by State: 1975 and 1976, Ranked in Order of Greatest Use

State	Total Purchased Fuels and Electric Energy			
	10 ¹² Btu		Cost (\$10 ⁶)	
	1975	1976	1975	1976
North Carolina	82.6	88.4	253.8	289.0
South Carolina	58.2	64.9	159.8	188.0
Georgia	41.8	46.7	113.8	135.8
Virginia	17.5	20.2	46.9	54.9
Alabama	15.7	16.8	43.3	52.0
Massachusetts	12.4	13.4	34.0	40.3
Pennsylvania	13.3	13.0	39.3	42.5
New York	9.5	8.8	28.5	28.7
New Jersey	10.6	7.9	28.6	23.7
Tennessee	7.0	7.2	18.5	21.6
Connecticut	5.4	5.5	15.7	17.8
California	4.5	5.2	8.8	12.0
Rhode Island	4.8	4.9	15.1	15.3
Maine	2.9	3.0	7.5	7.9
Ohio	2.9	2.8	6.5	6.6
Arkansas	2.4	2.4	4.0	4.8
New Hampshire	1.8	2.4	5.1	6.7
Texas	2.1	2.2	5.7	7.6
Mississippi	2.1	2.1	4.7	5.9
Kentucky	1.9	2.1	4.4	5.3
Illinois	1.2	1.2	2.7	3.0
Oklahoma	1.1	1.2	1.3	2.1
Others ^a	4.6	5.4	13.1	16.8
Industry total	307.1	328.6	862.8	990.8

^aWisconsin, Delaware, Michigan, Florida, Louisiana, Minnesota, Maryland, Oregon, Missouri, Indiana, and West Virginia.

Source: Ref. 13.

Table 2.5 Quantities and Costs of Purchased Fuels and Electric Energy in the Textile Industry (SIC 22) in North and South Carolina and Georgia, 1976

State and SIC Code	Fuel Oil						Coal		Natural Gas		Electric Energy		
	Purchased Fuels (10 ⁹ Btu)	Total Cost (\$10 ⁶)	Distillate		Residual		Quantity	Cost	Quantity (10 ⁹ ft ³)	Cost (\$10 ⁶)	Purchased		Generated Less Sold (10 ⁶ kWh)
			Quantity (10 ³ bbl)	Cost (\$10 ⁶)	Quantity (10 ³ bbl)	Cost (\$10 ⁶)					Quantity (10 ⁶ kWh)	Cost (\$10 ⁶)	
North Carolina													
22 Textile Mill Products	57.7	106.9	1,779.4	24.1	3,322.9	42.3	443.9	13.4	9.6	17.2	9,022.2	182.1	106.9
221 Weaving mills, cotton	6.4	10.1	128.2	1.8	255.1	3.3	118.7	3.2	0.7	1.5	1,057.2	20.9	a
222 Weaving mills, man-made fiber	8.4	15.6	169.8	2.3	711.9	9.1	59.7	1.7	1.1	1.9	1,736.2	34.6	a
224 Narrow fabric mills	a	a	a	a	a	a	a	a	a	a	a	a	-
225 Knitting mills	16.7	34.0	734.0	10.2	1,015.4	13.0	a	a	3.6	6.2	1,651.2	34.8	b
226 Textile finishing, except wool	12.9	23.0	245.4	3.3	660.0	8.0	139.0	4.7	2.0	3.7	348.5	7.5	a
227 Floor covering mills	a	a	a	a	a	a	0	-	0.2	0.3	a	a	-
228 Yarn and thread mills	10.2	17.9	232.7	3.2	589.9	7.7	122.0	3.6	1.5	2.5	3,723.5	73.8	a
229 Misc. textile goods	1.3	2.9	a	a	a	a	a	a	a	a	219.7	4.5	a
South Carolina													
22 Textile Mill Products	43.1	70.9	294.6	4.1	2,163.6	26.4	327.1	10.4	14.6	21.2	6,393.6	117.2	a
221 Weaving mills, cotton	2.8	4.9	36.0	0.5	208.5	2.6	a	a	1.0	1.5	1,357.3	24.6	a
222 Weaving mills, man-made fiber	7.3	12.5	b	b	b	b	b	b	b	b	3,017.1	53.9	a
224 Narrow fabric mills	a	a	a	a	a	a	a	a	0.2	0.2	a	a	-
225 Knitting mills	3.5	5.8	2.4	c	214.0	2.7	a	a	1.8	2.4	383.1	7.1	c
226 Textile finishing, except wool	25.3	39.8	43.2	0.6	1,038.3	12.3	290.0	9.1	7.4	10.3	535.8	10.5	128.1
227 Floor covering mills	1.3	2.4	a	a	a	a	a	a	0.6	0.9	77.0	1.7	a
228 Yarn and thread mills	1.6	2.9	32.9	0.4	151.6	1.9	a	a	0.3	0.5	721.4	13.8	-
229 Misc. textile goods	a	a	19.3	0.3	48.6	0.6	a	a	0.4	0.6	214.6	4.1	-
Georgia													
22 Textile Mill Products	33.6	49.4	437.5	5.9	800.1	9.9	115.6	4.2	19.8	23.7	3,841.2	86.4	93.9
221 Weaving mills, cotton	5.7	7.6	a	a	77.0	1.0	50.7	1.8	3.5	4.3	824.6	18.5	67.9
222 Weaving mills, man-made fiber	2.8	3.8	a	a	44.1	0.6	a	a	1.6	1.9	763.5	16.3	a
225 Knitting mills	a	a	a	a	a	a	a	a	a	a	78.0	1.9	a
226 Textile finishing, except wool	3.7	5.1	64.3	0.9	84.3	1.0	-	-	2.4	2.7	199.5	4.3	a
227 Floor covering mills	14.3	21.7	235.4	3.2	349.8	4.4	a	a	8.4	10.3	561.4	13.6	a
228 Yarn and thread mills	3.8	5.9	79.7	1.0	80.4	1.0	a	a	2.0	2.4	1,003.5	22.3	a
229 Misc. textile goods	2.0	3.2(22)	a	a	a	a	a	a	0.8	1.0	350.7	8.1	-

^aWithheld to avoid disclosing figures for individual companies.

^cLess than half of the unit of measure specified.

^bWithheld because the estimate did not meet publication standards, either on the basis of the associated standard error of the estimate or on the basis of a consistency review.

^dEstimated error (given in parentheses) exceeds 15%; figure may be of limited reliability.

Source: Ref. 13.

Man-made Fiber, which used 3.0×10^9 kWh. In Georgia, SIC 227, Floor Covering Mills, accounted for 14.3×10^{12} Btu of purchased fuels, and SIC 228 for 1.0×10^9 kWh of electric energy.¹³

As shown in Table 2.6 and Figs. 2.6-2.8, the cost of purchased fuels and electric energy in the Southeast is relatively high, with no state paying the lowest rate shown. Furthermore, for some states, the cost of purchased fuels is proportionately greater than the cost of purchased electric energy (Figs. 2.7 and 2.8).

2.3.2 General Process Description

Textile processing is categorized as dry or wet processing. Dry processing consists of spinning, knitting, weaving, and tufting; wet processing consists of preparation (including singeing, desizing, scouring, bleaching, and mercerizing), dyeing, drying, and finishing. Major energy-consuming equipment includes boilers, dryers, climate control systems, and product construction machinery. The dry processes use climate control systems and product construction equipment, both of which have been extensively developed, and most of the energy used is in the form of electricity. Energy for wet processing, however, is primarily in thermal form, either as steam for boilers to heat dye liquors or as direct combustion in dryers. Because thermal energy is low in cost relative to electricity, engineering sophistication comparable to that of electrically powered systems and equipment has not yet been developed for thermal energy technology.¹⁰

Textile fibers are classed as natural, man-made, or synthetic. Natural fibers are those produced by plants or animals; man-made fibers are those made by man from natural materials such as cellulose and protein (cotton linters, wood pulp, and corn); and synthetic fibers are those made from other materials. Figure 2.9 is a flow chart of the major processes involved in the manufacture of fabrics from raw fibers. Each process is described briefly in Appendix B.

Table 2.6 Energy Costs for the Southeast
(per 10^6 Btu)

State	Purchased Fuels (\$)	Purchased Electric Energy (\$)
N. Carolina	>1.74	5.00-5.99
S. Carolina	1.50-1.74	5.00-5.99
Georgia	1.50-1.74	6.00-6.99
Tennessee	1.25-1.49	0.00-4.99

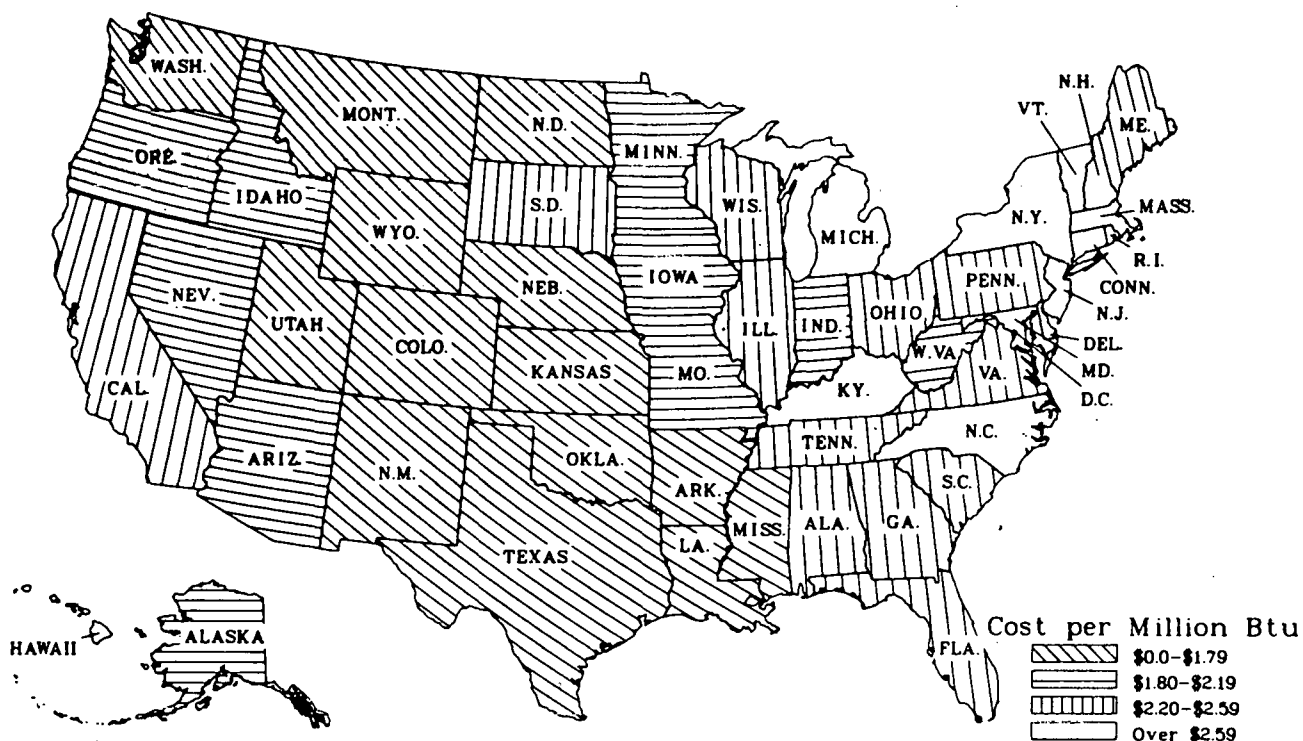


Fig. 2.6 Purchased Fuels and Electric Energy Consumed by Manufacturers in the United States: 1976 Cost per 10^6 Btu (Source: Ref. 13)

2.3.3 Discussion of Most Energy-Consumptive Processes

The most energy-consuming processes are those that require large quantities of heat -- dyeing and finishing. About 60% of the total energy used is for processes such as continuous and batch dyeing, drying between operations, and final drying and heat setting.³ In dyeing and finishing processes, the main source of heat is supplied by steam boilers. These boilers generally use the most economical fuel available. The fuels most commonly used are natural gas, oil, and coal, or a combination of these. Average daily steam demands range from about 10,000,000 to 100,000,000 pounds for the larger plants.¹⁴ The most commonly used type of dryer is the tenter frame dryer, which is a large frame through which the cloth feeds continuously at a constant width while it is dried by direct-combustion natural gas heat.

Drying and heat setting operations waste the largest amount of energy due to the weight processed and the required repetition. Plant personnel tend to use overly conservative operating conditions in an effort to reduce the incidence of defects, and tenter frame dryers are operated more slowly and for longer periods of time than necessary, often resulting in overdrying. Drying operations account for most of the energy used during continuous dyeing and finishing and printing.¹⁰ Atmospheric dye becks and related atmospheric equipment consume an inordinate amount of energy due to their design.¹⁰

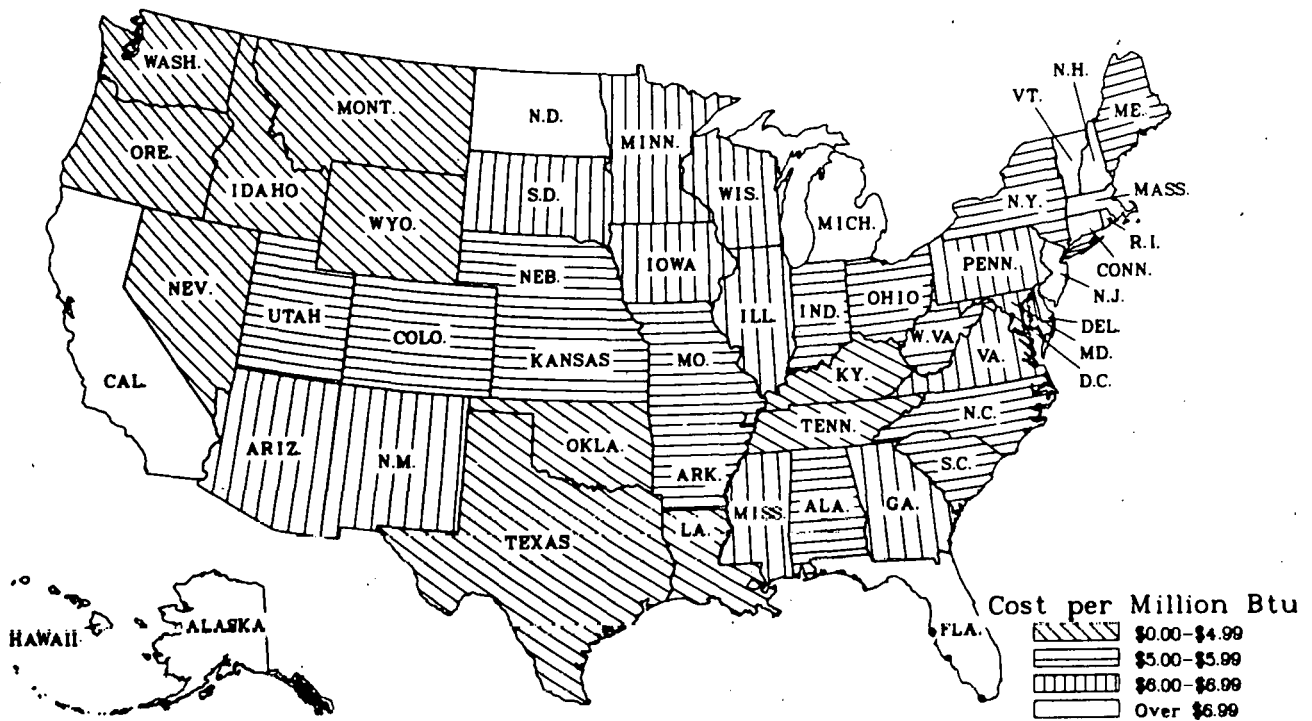


Fig. 2.7 Purchased Electric Energy Consumed by Manufacturers in the United States: 1976 Cost per 10^6 Btu (Source: Ref. 13)

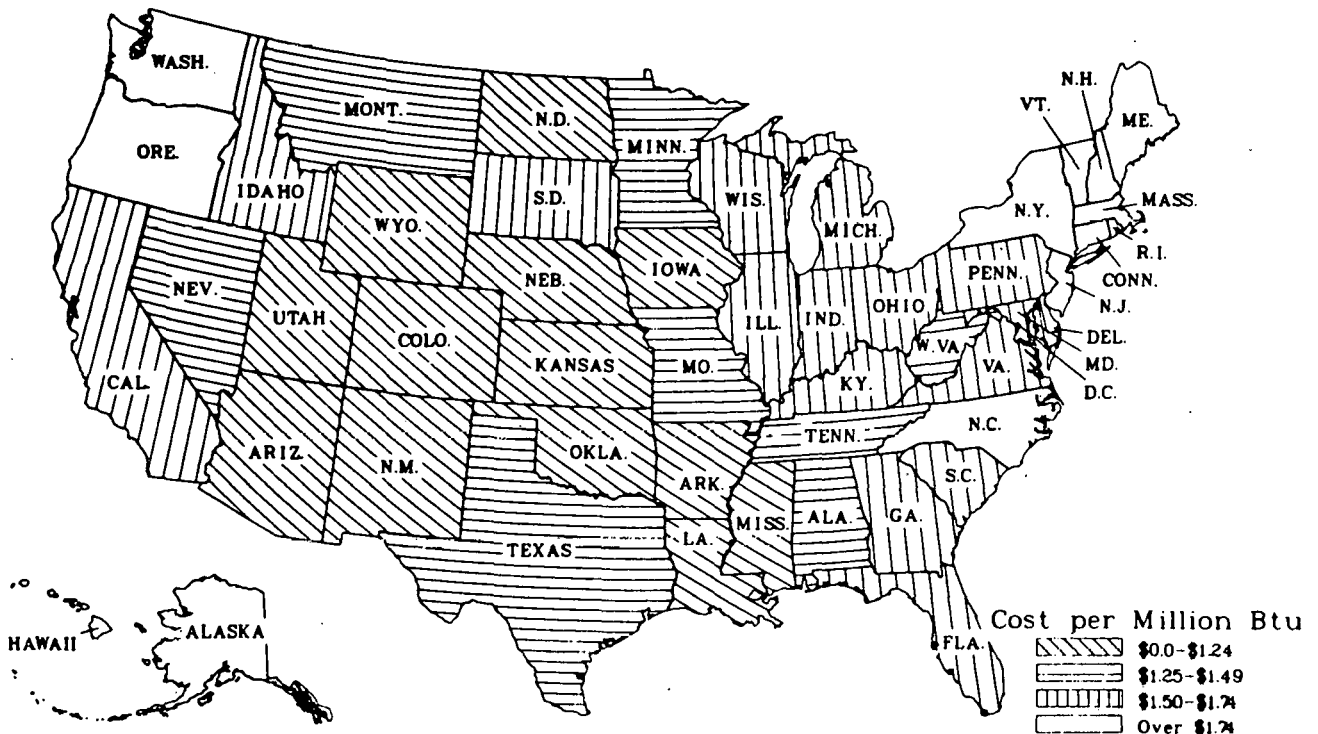


Fig. 2.8 Purchased Fuels Consumed by Manufactures in the United States: 1976 Cost per 10^6 Btu (Source: Ref. 13)

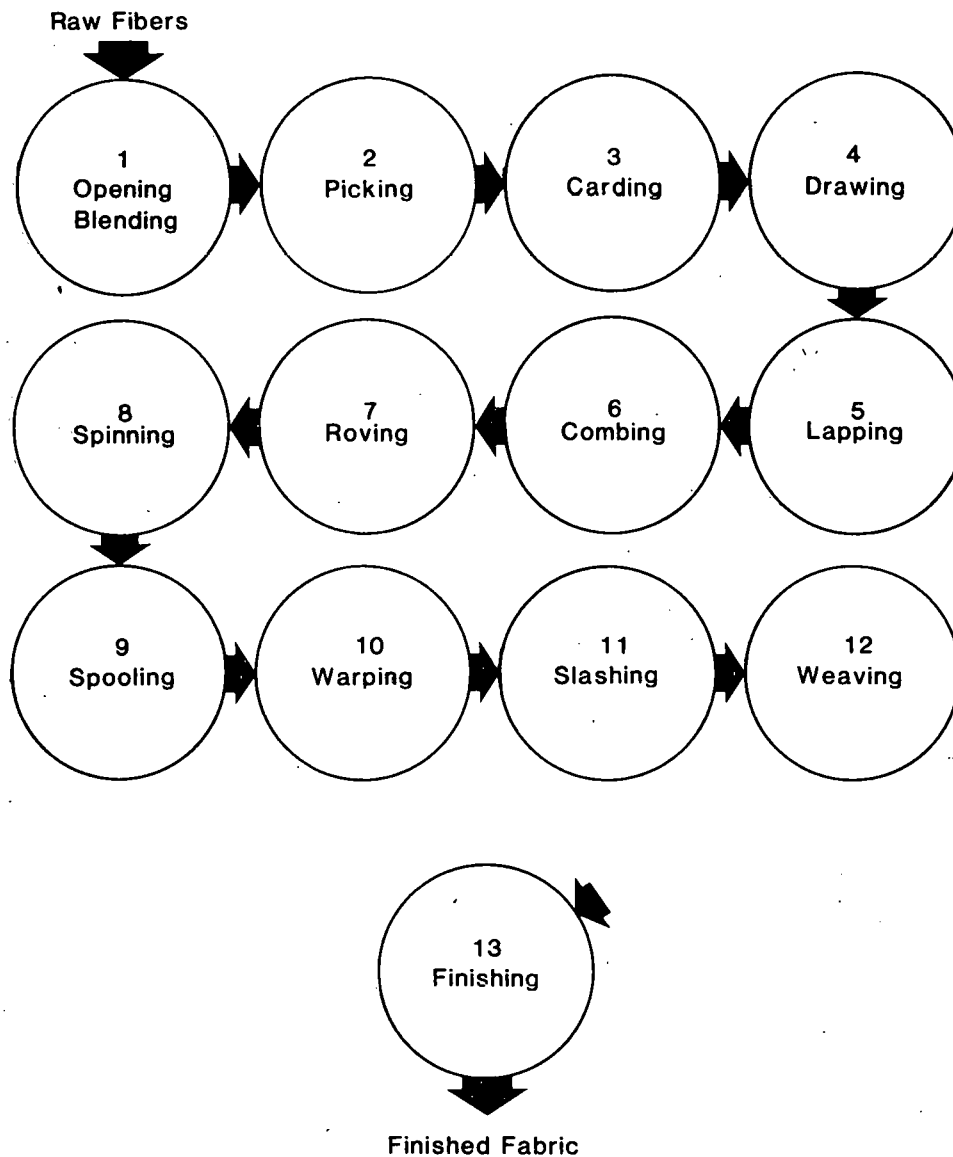


Fig. 2.9 Major Processes in the Manufacture of Fabrics from Raw Fibers (Source: Ref. 14)

In a recent report,¹⁵ drying operations and atmospheric beck dyeing were identified as two major areas where energy conservation research should be most productive. The results of research and development in these two areas are to be reported in a subsequent document.

2.3.4 Industry Response to Federal Energy Efficiency Target

Based upon the information provided by the major industry trade association (the American Textile Manufacturers Institute - ATMI) and companies reporting directly to DOE, DOE calculations of both the net and gross progress in SIC 22 indicate (Fig. 2.10) the progress of the industry through 1976 to be slightly above the target lines drawn from 1972 to 1980.¹⁶ The

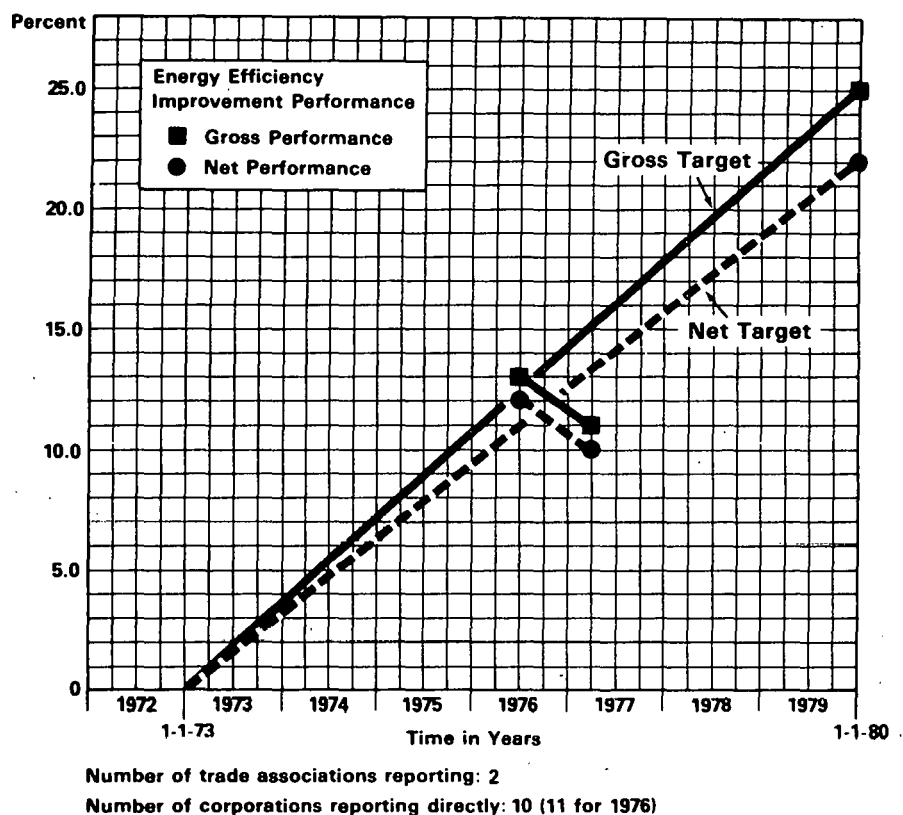


Fig. 2.10 Progress of Textile Industry (SIC 22) in Meeting FEA Energy Efficiency Target (Source: Ref. 15)

apparent decrease in energy efficiency improvement for the industry during the first half of 1977 may be the result of the record cold weather during early 1977. The reductions in production due to curtailed energy supplies (1222 plant hours were lost due to shortages of natural gas from Jan. 1, 1976 to June 30, 1977¹⁸) were not always offset by proportional reductions in energy consumption, as basic services (for example, security) continued to be provided even to production facilities with no significant output. Such effects of adverse weather conditions may offset temporary efficiency improvements in a given year but do not carry over to succeeding years; so the performance values for the industry with "normal" climate should better reflect the progress to date than will a trend line which includes the values reported during years with extreme climate.

The ATMI canvassed its members and provided information to DOE on measures being used or installed to help meet the energy efficiency target.^{16,17} Those measures that were reported as being effective in improving energy efficiency were characterized in six general categories. These categories and the percentage of reporting companies implementing the measures through 1976 are presented in Table 2.7. The measure used by the highest percentage of companies reporting (80%) was energy management. With the rise in energy costs, particularly electricity, even smaller companies are beginning to consider energy management.¹⁹

Table 2.7 Energy Conservation Measures Implemented by Textile Firms, by Category, and Percentage of Firms Using Measures in Each Category through 1976

Category of Energy Conservation Measures	Measures Included	Percent of Reporting Corporations Using Measure
Waste energy recovery	Use of waste heat from compressors, dryers, kilns, and furnaces; recovery of the heat or cooling effect from ventilation exhaust air; increased efficiency of heat use obtained by increasing the size of heat exchangers.	50
Improved methods of electrical energy use	Optimization of plant power factor and motor sizes, and use of more efficient lighting sources.	60
Increased boiler and steam efficiency	Minimization of boiler blow-down; repair or installation of steam traps and condensate return lines; better maintenance of burners, injection systems and the boiler as a whole; improved scheduling of boiler operations.	50
Increased use of insulation	Insulation of steam lines, condensate lines and process equipment; increased building insulation.	70
Process equipment improvements	Modifications of processes or process equipment to minimize energy use; replacement of equipment with new, less energy-intensive equipment.	40
General energy management	Establishment of employee awareness programs, energy audits and controls; shutdown of units not in use; lowering and raising of thermostat levels to reduce energy use; use of waste as a fuel source; establishment of corporate and plant energy goals; top management review of results.	80

Source: Ref. 16.

Energy demand by fuel type is shown for 1972, 1976, and the first six months of 1977 in Fig. 2.11 and in Table 2.8. Fig. 2.11 shows a trend toward increased use of fuel oil and, to a lesser extent, coal, and decreased use of natural gas. Demand for electricity has remained about the same. According to data reported by the ATMI,²⁰ energy efficiency was 8.9% higher in 1976 than in 1972 (21.8×10^6 Btu/ 10^3 lb input material in 1972). Energy efficiency improvement through the first half of 1977 is estimated at 9.2%. The ATMI also reported energy efficiency adjusted to eliminate energy related to compliance measures as an 11.1% improvement for 1976 and a 10.6% improvement for the first half of 1977.²⁰

During the first half of 1977, in response to sharply increased costs for all types of energy and to natural gas curtailments, textile manufacturers stepped up their efforts in housekeeping and maintenance, process modifications and monitoring of energy, in some cases down to the level of individual pieces of equipment. Automatic controls are being studied or used for electric power management of process equipment and for heating and ventilating systems. New and different dyeing techniques are being employed. In some cases, precise moisture sensors are being used to optimize energy use in fabric drying operations. Manufacturers report that increasing energy costs have resulted in a higher priority for funding of energy conservation projects and the assignment of more personnel to energy management. Manufacturers also are asking for and receiving data related to energy efficiency of new equipment from machinery manufacturers.

2.3.5 Targets for Use of Recovered Materials

As part of the National Energy Conservation Policy Act of 1978, Congress directed the Department of Energy to establish targets for four industrial sectors, including textile mills. The targets are to represent the maximum increase that is technically and economically feasible in the use of materials recovered by energy-saving techniques that an industry can achieve progressively by January 1, 1987. A discussion of these targets is beyond the scope of this report; however, information on the proposed targets for the textile industry is available in Ref. 21.

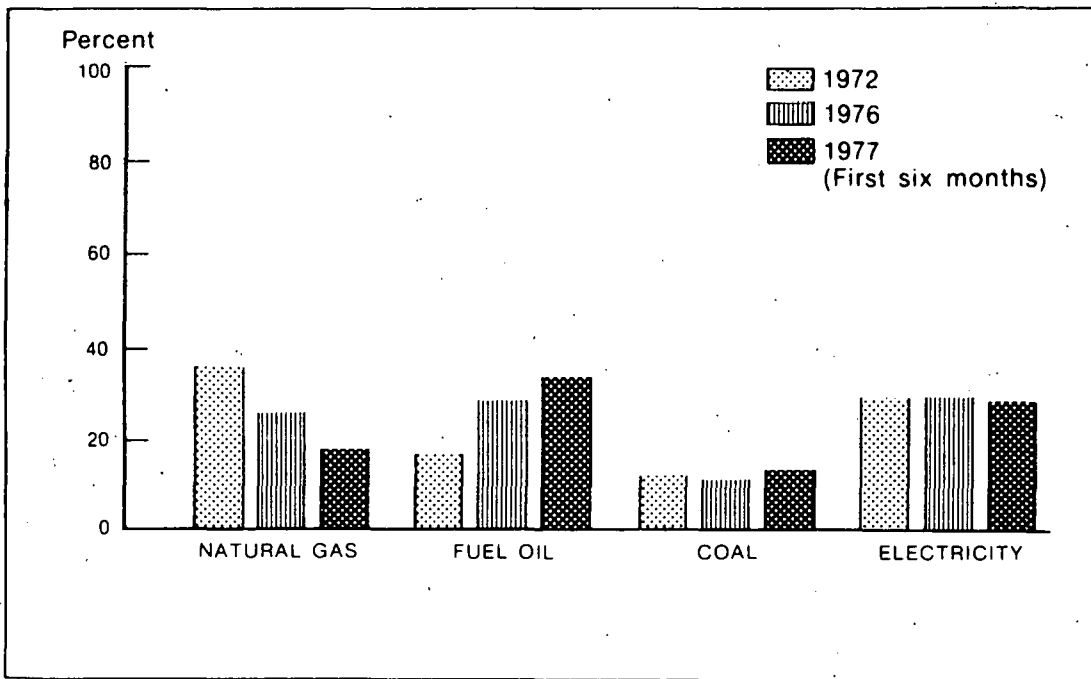


Fig. 2.11 Energy Demand in the Textile Industry, by Primary Fuel Type (Source: Ref. 19)

Table 2.8 Energy Demand by Fuel Type for 1972, 1976, and the First Half of 1977

Energy Source	1972	1976	First Half 1977
Natural gas	38.58%	25.62%	18.04%
Propane and LPG	0.89	1.10	2.10
Distillate fuel oil (including diesel and kerosene)	2.64	4.14	5.38
Residual and crude oil	15.51	25.14	28.94
Gasoline (including natural and still gas)	0.39	0.32	0.18
Coal, bituminous	12.60	12.42	14.20
Coal, anthracite	0.26	0.18	0.20
Electricity	29.12	30.59	29.99
Other	-	0.49	0.95

Source: Ref. 20.

3 BARRIERS TO THE IMPLEMENTATION OF ENERGY- CONSERVING TECHNOLOGIES

A survey of textile companies conducted by Lowry et al.³ indicates that economic considerations form the primary barrier to the implementation of energy-conserving technologies in the textile industry. A sufficiently short payback period or acceptable return on investment must be achieved to justify an energy conservation expenditure.³ A second barrier closely associated with the first is technical acceptability; any technology which slows production or alters product quality is not likely to be accepted by the textile industry. The third barrier derives from the conflict between commitments of capital for compliance with environmental and safety regulations and for energy conservation measures. The fourth barrier identified in the survey is lack of information and technical expertise.

3.1 ECONOMIC BARRIERS

For most companies the economic barrier to energy conservation entails the justification of capital expenditures for energy conservation -- either a sufficiently brief payback period or an adequate return on investment (ROI) must be achieved. Capital cost or availability or both are a problem for many companies.³ The payback criterion is used by most small companies, with a period of from two to five years considered acceptable; however, large companies use the ROI criterion almost exclusively, with a range of 25% to 38% considered acceptable.³ Costs associated with compliance with federal air and water standards (see Sec. 3.3.3) are becoming an increasingly important factor in calculating ROI. Payback period, ROI, and other methods of evaluating expenditures are discussed in Sec. 3.1.1.

Although financial criteria are generally of primary importance, other factors can affect decisions regarding expenditures for energy-conserving technologies. For example, in most companies the threat of a plant shutdown overrides other decisions, and often expenditures for fuel storage or other means of ensuring production are not subjected to the same financial criteria as are other expenditures.^{3,22,23}

Despite the advantages offered by more sophisticated methods of analyzing capital expenditures, payback period and ROI have traditionally been the more popular criteria in industry for several reasons. One is that the evaluation criteria normally used are set aside to permit industry to comply with regulations or to ensure continued production. Another reason is that many proposed energy conservation projects are sufficiently small in scale that sophisticated analysis is unnecessary and might require more time and money than the project merits.²³

Although an industry-wide trend toward more sophisticated analysis is expected,²³ it is likely that the textile industry will continue using payback period and ROI to evaluate investments. One reason is that most plant operation is left to operating personnel, who, lacking expertise in sophisticated financial arrangements, are likely to use these traditional methods of economic evaluation. One possible change in the evaluation criteria used could be a trend toward increased use of ROI by smaller firms or new criteria by both small and large firms (see Sec. 3.1.1) as energy management systems increase.

3.1.1 Analysis of Capital Expenditures

Basically, capital expenditures are analyzed by comparing the net investment required for new equipment or changes in operation with the economic gain represented by the estimated operating cash flows generated by the investment. In addition, the availability and cost of capital funds must be analyzed.

A capital-expenditure analysis requires consideration of the major elements of time, cost, and revenue of a project. These include:

- Costs incurred before construction
- Fixed capital costs
- Installation costs
- Startup costs
- Availability of working capital
- Subsequent investments required
- Sales price and volume trends
- Annual expense
- Tax effects
- Salvage value

Since capital expenditure occurs early in a project whereas economic gain is realized over the lifetime of the project, the time-value of money is a fundamental component of expenditure evaluation. Techniques that take the time-value of money into account are thus preferred.²⁴ No single criterion can be used as an absolute measure for evaluating profitability and for comparing alternative investments on an economic basis. In some cases, a continuing evaluation may be desirable. Although there are advantages and disadvantages to each technique, rate of return by discounted cash flow seems to be the most generally suitable index. However, no single index number alone can show all the relevant factors.

The internal rate of return required for justification of an expenditure varies with the company and the general economic climate. In general, the rate of return required for ancillary investments (those not associated with profitability or expansion of the primary market) is higher than that required for product-oriented investments. Changes in financial incentives can significantly alter the expected rate of return, and thus the probability that a company will invest.

The basic financial criteria used in the textile industry to evaluate investments, including a discussion of capital cost and availability, are presented in the following section.

3.1.2 Financial Criteria Used to Evaluate Investments

Capital investments in energy conservation technologies traditionally have been evaluated on the basis of the resulting profit, production, or

cash flow. However, energy managers and economists are beginning to consider other factors in their analyses of energy conservation expenditures. R.L. Secor²⁵ and others have discussed these new methods of economic assessment. According to Secor, some intangible factors that should be considered in such evaluations include the following:

- The value to the company of continued production during a fuel supply limitation,
- Escalation of savings (6-8% per year), and
- Savings in terms of alternate-fuel dollars, not curtailed-fuel dollars, both when no alternative fuel is needed to maintain production and when no alternative fuel is needed to increase production.

Gross Payback Period

Gross payback period is a simple, quick method often favored by smaller companies to evaluate investments. It is the ratio of capital expenditures to the annual gross (pretax) savings at the time of investment. In this method, it is assumed that the flow of net benefits is consistently positive after an initial investment period. The method is not sensitive to the timing of cash disbursements or cash receipts within the recovery period. Despite its limitations, it is often used to select projects because it does not require the algebraic calculations required by other methods..

Return on Investment: Discount Cash Flow

One of the most commonly used techniques, particularly by large companies, is internal rate of return or discounted cash flow (also called profitability index, interest rate of return, or the investor's method). This technique is based on the assumption that the sum of the present value of all cash flow returns associated with a given project equals the initial capital expenditures:

$$C_0 = \sum_{n=2}^N \frac{\text{net cash flow (n)}}{(1 + i)^n}$$

where:

C_0 = capital expenditure by investing company,

i = internal rate of return,

n = rate of return, and

N = economic life in years.

There are three advantages to this method: (1) it provides a sensitivity to the relative timing of cash disbursements and receipts and thereby recognizes the time value of money; (2) it varies with changes in factors

such as tax regulations, depreciation, accounting, energy costs, inflation, financing procedures, escalation in savings and costs; and (3) it allows comparison of alternative investments to each other and to the net cost of borrowing. The disadvantage to this technique is the inherent assumption that funds recovered are reinvested at the same rate of return. This assumption can limit its utility when comparing alternative investments with unusually attractive returns.²⁴

Capital Cost and Availability

The availability and cost of capital influence the evaluation of a proposed expenditure. Relevant factors include the cost of internal funds, cost of debt, cost of equity capital, average cost of capital, marginal cost of capital, and optimal debt-equity ratio. The usual procedure for computing the cost of capital is to take a weighted average of the costs of different funds raised and include consideration of optimal debt-equity ratios and what the investment will do to stockholders' equity or to the current market price of the stock. This index is especially important in the consideration of incentives to mitigate capital availability barriers.²⁴

3.2 DISCUSSION OF ENERGY-CONSERVING TECHNOLOGIES

Energy-conserving technologies have been developed for the textile industry, and the technical feasibility of many of these has been demonstrated by either in-plant demonstrations or pilot-scale operation. Thus there are no major technological barriers to the implementation of energy-conserving technologies. Instead, the primary barrier to their adoption is acceptance by the industry.^{3,26} Effects on production rate and product quality are of primary concern in the textile industry. Because the primary customer for textiles is the apparel industry, textile manufacturers must be prepared to modify processes quickly -- what is fashionable this year may not be next year -- and product quality must be consistent. In addition, because the textile industry operates on a profit margin substantially lower than the all-industry average (see Sec. 2.2),⁶ a decrease in production can affect a company's profitability.

Many textile manufacturers are reluctant to set up in-plant demonstrations of new technologies because operational problems not apparent in the design or pilot-scale stages may develop during in-plant operation.²⁶ Little research has been done to formulate demonstration methods specifically designed to enhance the market penetration of energy-conserving technologies.* If such methods could be formulated, the major barrier to the adoption of these technologies would be eliminated in many industries, and in the textile industry in particular.

An additional problem is that once a technology has been demonstrated and fully documented, many companies do not have the expertise required

*See, for example, "Summary of Active Awards and Completed Projects," National Science Foundation (Jan. 1978); and "Program Announcement for Extramural Research," National Science Foundation (Dec. 1978).

to implement the technology. A follow-up project is needed (involving several companies) designed to provide outside assistance for the initial stages of implementation.

Major energy-conserving technologies that are sufficiently developed to be currently available or in pilot-scale stages of operation are briefly described in the following sections. Because the major fraction of energy use in the textile industry is for heating and evaporating water, water conservation or elimination of water use is a major energy-saving measure. Methods or equipment that provide improved contacting, mixing, or elimination of water from the fabric are discussed in Sec. 3.2.1 as advanced aqueous systems and in Sec. 3.2.2 as solvent systems. Also described are foam finishing and dyeing (Sec. 3.2.3), mechanical predrying (Sec. 3.2.4), and optimization of tenter frame dryers (Sec. 3.2.5).

3.2.1 Advanced Aqueous Processing

Sizing Recovery, Wash-Water Reuse

Most woven goods require the use of warp size (traditionally starch) during manufacture to prevent damage to the warp from excessive abrasion during weaving. The size is generally removed as the first operation in fabric finishing. Polyvinyl alcohol (PVA) is the material of choice for warp sizing of synthetics, such as polyester and polyester/cotton blends. Its use in the textile industry accounts for about 60% of all sizes used. PVA is generally removed from fabric by washing with detergent in water at temperatures of 190-200°F, with much energy lost in the waste water. It has been demonstrated that PVA can be recovered by ultrafiltration through temperature-resistant, chemically coated, inert carbon tubes and the purified wash water recycled to the process.^{27,28} This process has now been commercialized* and there have been no serious operating problems with the filtration system after two years of operation.

Further development of the techniques of PVA reclamation, and the extension of its use to other fibers and weaves, will probably occur on the basis of good return on investment. The modular construction of the recovery units would appear to make the technique applicable even to small mills.

Water Conservation

Washing or rinsing after wet processing such as dyeing uses one to three times as much hot water as the process itself and in some operations (e.g., continuous dyeing) much more. Hence, improved washing methods offer significant energy savings. Techniques being developed include more effective continuous counter-current rinsing. In one proposed method,²⁷ fabric is rinsed at slightly elevated pressures in continuous equipment to remove

*A PVA system designed and constructed by Gaston County Dyeing Machine Co. is in operation at the J.P. Stevens Mill in Clemson, S.C.³⁰

chemicals more efficiently. Experimental units using vibrating-reed jet washers and cam-driven beater rollers* are on field trial in the textile industry. Mechanical devices to increase water turbulence and sonic devices for increased removal of dirt and excess dye²⁹ are being developed.

Reuse of hot wash waters from dyeing operations after treatment by reverse osmosis (hyperfiltration) is the objective of an EPA demonstration project.^{30,31} Successful pilot-scale tests at one plant have shown that 65-90% of the water can be removed and that the concentrate containing all the chemicals can, in some instances, be reused in dyeing.

Dye Bath Reuse¹⁷

A typical batch dyeing operation, once finished, will have appreciable quantities of auxiliary chemicals, a small quantity of dyestuff, and a large amount of hot water in the dye bath, which is flushed down the drain. In some cases, a small part of the energy is routed through various types of heat exchangers, but in general, approximately half of the energy that is lost in batch dyeing processes is dumped down the drain.

Researchers at the Georgia Institute of Technology are analyzing the dye concentration and raising it back up to the concentration level required for subsequent dyeing so that the whole bath can be reused. The Georgia Tech study began with carpet dyeing, because color matching is not nearly as critical as in other textile operations. In addition, the range of dyestuffs used in carpet dyeing is relatively limited. In the laboratory, carpets were successfully dyed to the same shade five times from the same dye bath using dispersed dyes, and nylon carpet was dyed to ten different shades using dispersed dyes and reusing the dye bath for those ten dyes. Subsequent work at Georgia Tech has included the use of acid dyes on nylon, which is more difficult. This work has led to dyeing of different textile products. For example, hosiery dyeing is similar to carpet dyeing, and hosiery is now being dyed on a batch basis, reusing the dye bath up to 41 times in plants.⁵ Other areas of dyeing studied include package dyeing of polyester yarns and reactive dyeing of cotton and cotton/polyester blends.

Combined Operations

In the area of preparation, Georgia Tech has been examining the possibility of combining operations so that desizing, scouring, and bleaching take place in a single pad-steam-wash operation. In this way the number of steam-washing operations can be reduced and energy can be conserved.

Processing at Low Ratios of Dye Liquor to Cloth

A variety of dyeing machines are currently used in the textile industry. Some of these, including open dye becks and pressurized dye machines,

*Riggs & Lombard, High Efficiency Washer, observed at Charlton Woolen, Charlton, Mass.⁶

have been in service for a long time. Considerable energy can be saved by enclosing the open becks and controlling stack losses to prevent steam escape. Pressurized machines use considerably less water. It is estimated that improving the average level of operations to that of the best existing in the industry might save 15% to 20% of the current energy use in dyeing operations, or about 2% to 3% of the total energy used in a typical mill.⁶

Additional energy could be saved by reducing the amount of water used in dyeing. However, as the ratio of dye solution to cloth decreases, the difficulty of obtaining uniform color increases. This problem varies with the dye and fabric. However, processes and equipment have been developed for dyeing at very low ratios of dye liquor to cloth with uniform dyeing.³⁴ Liquor-to-fabric ratios of 5:1 have been demonstrated for batch dyeing of knit fabric. The ratio for foam dyeing is even lower (1:1). This is a considerable reduction from the commonly used 25:1 to 10:1 ratios, with consequent savings in energy and water. Applicability of such dyeing techniques to a wide range of textile fabrics has been demonstrated in pilot-plant work by the equipment manufacturers,³⁴ but adoption by the industry will require capital investment in new equipment and additional experimentation.

Continuous dyeing of woven goods, particularly pad dyeing of polyester with dispersed dyes (thermosol process) and of cotton with reactive dyes, is commonly practiced; however, not all shades and fabrics can be processed in this manner.

Low liquor-to-fabric ratios have also been successfully used in other process operations such as scouring (10:1 from the usual 20:1) and washing (8:1 from 25:1). The use of an 8:1 in place of a 25:1 water-to-fabric ratio for open-width washing of woven goods has been demonstrated in practice,³⁶ but its applicability to all types of fabric needs further demonstration.

Vacuum Impregnation and Extraction

In vacuum impregnation,³⁷ the fabric contacts a perforated cylinder, and air is extracted by the vacuum. Dye solution contacts the fabric before the fabric is returned to atmospheric pressure, thus promoting penetration of dye into the fabric. This technique is particularly useful for dyeing heavy fabrics, which are difficult to dye uniformly by conventional means. Vacuum impregnation is also potentially applicable to various finishing processes, such as durable-press and flame-retardant finishing.

Evaporation of water is the most energy-consuming part of textile processing. Typically, wet fabric that has been squeezed between mechanical rollers still contains 50-100% of its weight as water, depending on the particular fabric being treated. Vacuum extraction by porous rollers will reduce the water content more effectively, thus reducing the amount of energy required for drying.³⁸

Finishing (Drying)

Several energy-efficient finishing techniques are under development, including application of low-temperature curing resins and radiation curing

of resins;³⁹ however, these techniques have not yet been widely implemented commercially (one firm uses low-temperature curing resins⁵). One technique being used commercially⁴⁰ is the use of finish solutions, emulsion, or suspensions that are made with considerably less water. In the conventional method, dry fabric is dipped into a finish pad and the excess finish solution is then expressed by squeeze rolls, producing a total water pickup of 60% of the weight of the fabric. The advanced technique uses a vacuum extractor (or a transfer roll) that limits pickup to about 16% by weight of the fabric, thus reducing the water content that must be evaporated in the dryer. An additional benefit claimed is that less finish is lost from the fabric during heat setting.

3.2.2 Solvent Processing⁴¹⁻⁴³

Solvent processing offers the prospect of substantial energy savings over conventional aqueous processing, principally because about eight and one-half times more energy is required per pound to heat and vaporize water (1162 Btu/lb) than to heat and vaporize typical organic solvents (135 Btu/lb). Further, because nonaqueous solvents have higher vapor pressures, drying rates are appreciably faster. Solvent processing is potentially applicable to most major wet processing operations such as sizing and desizing, scouring, bleaching, dyeing, and various finishing processes. However, solvent processing is not without major economic and environmental disadvantages. Direct solvent losses from the process can be in the range of 5-8%, and most of the solvent must be recovered to make the economics of the processes acceptable and to meet air quality requirements. However, there are installations in the textile industry with carbon adsorption systems for solvent recovery, and users claim acceptable economics and compliance with air pollution regulations.

To date, there has been no appreciable commercial use of solvent finishing for woven goods. However, solvent processing has established a firm, if specialized, position in the finishing of synthetic knit fabrics. Solvent processing has also found commercial use where superior fabric properties are desired, for example, in the application of stain-repellent finish to upholstery and drapery materials. In this case, aqueous treatment is not always possible, because the fabric is sensitive to water. Similarly, solvent scouring and finishing of synthetic knit fabrics is widely practiced, because improved quality is obtained by avoiding contact with water. Some finishes, furthermore, are not available in water-soluble or water-dispersible form and can be used only in solvents. However, before all-solvent processing could be introduced, considerable investment in new equipment would be required, together with development of an expanded range of solvent-compatible reagents, dyes, and finishing chemicals.

Sizing and Desizing

Starch-base size can be desized by treating the sized fabric with an enzyme suspension in a solvent followed by steaming to remove the solvent.⁴⁴ The degraded starch is not reusable and goes to the waste treatment plant. Polyvinyl alcohol (PVA), carboxymethylcellulose (CMC), and acrylic size can also be removed by dissolution in solvents. In this case, reuse of the size is possible and would reduce process and waste treatment costs.

Scouring, Bleaching, and Mercerizing

The widest application of solvent processing to date has been in the use of solvent scouring⁴³ to prepare knit fabrics for dyeing. Batch-type dry cleaning equipment is used commonly, both in Europe and the United States. Continuous scouring and finishing equipment for circular knits has recently been made available from a number of suppliers and is engineered to minimize air pollution problems. Under the processing conditions, chlorinated solvents are not retained inside the fiber.

Dyeing

Continuous-dyeing and exhaust-dyeing systems have been examined in great depth, but there are major problems in both areas that must be solved before extensive application of solvent dyeing can be achieved. As much as 5-7% by weight of chlorinated solvents may be retained by polyester fiber after dyeing.⁴³ This solvent must be removed and recovered in subsequent operations. The widest application of solvent dyeing to date has been in batch dyeing of synthetics, such as nylon knit sportswear.

Experimental work has shown that superheated solvent vapor can be used as a fixation medium for disperse dyes on polyester,⁴⁵ for disperse and acid dyes on polyamide fibers, and for reactive dyes on acrylonitrile fibers.

Solvent dyeing of cotton/polyester blends may be possible as a result of recent developments, where the cotton component was dyed using dimethyl formamide (DMF) and perchloroethylene.⁴⁶

Finishing

Durable-press finishes for cotton and cotton synthetic blends can be applied from chlorinated solvents.⁴⁷ Chemicals used must either be emulsified in the solvent or must be chemically modified to make them soluble, which requires that the treated fabric be exposed to steam to effect fiber swelling and penetration. At present, most finishes are designed to be applied from aqueous solution as emulsions or dispersions. This situation is partly a result of integration with existing water-based processing, so new approaches could be tried for a mill based completely on solvent processing.

3.2.3 Foam Finishing and Dyeing

The foam finishing and dyeing process uses either water or solvents, and is reported to result in reduced water consumption of at least 50%, and in some cases 80-90%, with virtually no aqueous effluents.¹⁸ The process could be retrofitted to all pad/dry/cure finishings ranges and continuous dye ranges, but not to beck dye ranges.

The foam dyeing process consists of preparation of a concentrated solution (or dispersion) of the chemical or chemicals, as, for example, a dyestuff in water (other dispersing media could also be used), and incorporation into the concentrate of suitable foaming aids. The concentrate is then

mechanically foamed, and the foam applied to a moving textile web by means of some equipment such as a knife over a roll coater. The foam is then caused to collapse and flow over the fibers. This can be done by passing the foam-coated fabric through a pad mangle or by using a foam that collapses when heated. The coated fabric is then passed through a conventional oven to remove the small amount of water used in the concentrate and to fix the dye or finish on the fabric.¹⁸ One method by which foam can be applied to textile fabrics is illustrated in Fig. 3.1. In the method shown, the foam is applied to the fabric at the knife (7). The coated foam is collapsed by the padding unit (9) to obtain a uniform finish coating on the fabric. Alternatively, a vacuum (8) may be used to collapse the foam. When the foam is collapsed, its viscosity drops sharply and the finish formulation flows over the fabric uniformly. Standard production-scale mechanical foamers are commercially available.⁴⁸

Conventional drying methods are used to evaporate the remaining liquid from the fabric. Drying ovens usually use natural gas to heat the ovens. Drying time is a function of the percentage of excess liquid in the fabric, the range (line) speed and the oven temperature. It is in the drying phase that energy can be saved by the use of foam. A low moisture level in the fabric (15-35% foam versus 100% for conventional applications) means that there is less excess moisture to evaporate in the drying phase. This means that either the range speed can be increased or the dryer temperature reduced, or both. In any case, energy used per yard of material can be substantially reduced.⁴⁸ A key factor in realizing such a reduction in energy use is avoiding afterwashing. If the fabric is washed, then it must be dried like conventionally dyed fabric, with similar energy requirements for drying.

In recent tests of foam finishing where wet pickups were reduced by about 50% and dryer temperatures were unchanged, energy savings ranged from 35% to 50%. Where oven temperatures were dropped 100°F to 125°F, energy savings increased from 70% to 85%. This could amount to energy savings of 70-170 trillion Btu per year with total conversion by the textile industry to foam processing.⁴⁸

Not considered in the data presented is the considerable energy involved in the manufacture of the foaming agents and stabilizers. Although the energy is not used in the textile finishing process itself, a measure of the energy used in the manufacture of foaming agents needs to be incorporated into a methodology which is intended to measure net energy conservation of industrial technologies. Likewise, the additional mechanical energy needed to mix the liquid and air needs to be included in a total net energy balance analysis. These should include the electricity used in running a mixing motor and in moving large quantities of air into the mechanical mixer. This increased energy consumption would offset some of the energy conserved in the drying process. Other applications of foam processing are under active consideration. Foam dyeing and printing are currently undergoing production trials. Foam slashing and fabric preparation are under active investigation, and the feasibility of foam finishing and foam printing in a single operation has been demonstrated in the laboratory. Energy savings in all of these operations would be achieved through lower drying temperatures and faster range speeds, assuming that afterwash is avoided.

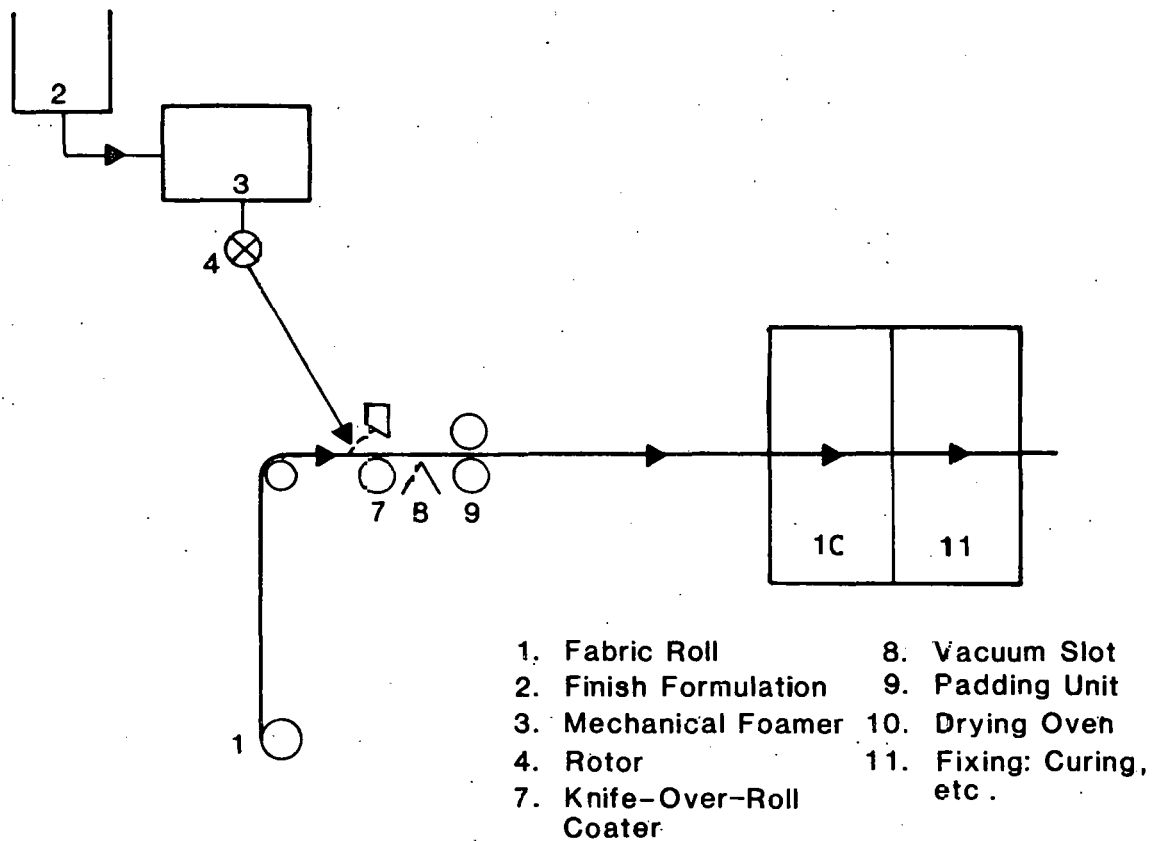


Fig. 3.1 Schematic Diagram of Continuous Foam Finishing Using Knife-Over-Roll Coating (Source: Ref. 18)

3.2.4 Mechanical Predrying

Researchers at the Georgia Institute of Technology are examining methods of energy-efficient moisture removal -- use of a vacuum or reduced pressure and subsequent thermal treatment to reduce the amount of energy necessary for moisture removal in predrying.¹⁸

Also being investigated are "hot water cans." Fabrics can be dried by using steam cans that contain hot water (about 160-180°F). The time required to dry fabric would of course increase as the water temperature decreased. The drying time required for different temperatures and fabrics has been examined to determine if this is economically viable. An analysis is being conducted on a stack of four steam cans where the first two stacks contain hot water and the second two contain steam. Many textile firms are concerned that they are overdrying with steam cans. If the residence time and thermal treatments can be adjusted to the correct level of drying, energy can be saved.

Finishing systems are being examined as a source of 160-180°F waste water for these hot water cans. Since this water contains contaminants, it may have to be filtered or purified in some way.

Another drying technique being considered at Georgia Tech is the "Machnozzle," which was invented in Holland by the Brugmann Company. There are several companies in the U.S. that have the Machnozzle, although its application is not yet well-defined. Papers have been published on its effectiveness in Holland, but there has been no experience with it here. To determine the most effective applications of the Machnozzle, the Georgia Tech team intends to investigate methods of predrying using an experimental model and comparing their operating data with European data. Georgia Tech will also be investigating the routing of condensed low-pressure waste steam from the Machnozzle back to the hot water can discussed earlier.

3.2.5 More Efficient Operation of the Tenter Frame Dryer

The goal of a research project at Clemson University is to develop operating guidelines for optimizing the operation of tenter frame dryers (see Fig. 3.2). Since experiments on production dryers are difficult to perform, a mathematical model describing the drying process has been developed and is being refined. With this model, a dryer can be simulated on a digital computer for various operating conditions, with only the most promising results verified by plant tests.

The model, which consists of a set of ordinary differential equations that are solved simultaneously, predicts fabric temperature and moisture profiles along the length of the dryer. At present it is first necessary to determine four parameters for each dryer-fabric combination by fitting the model to experimental temperature profile data. The goal of researchers is to be able to predict a set of dryer parameters and a set of fabric parameters without experimental data having to be obtained for that particular dryer-fabric combination. Once this is accomplished, the study of the effects of factors such as hot air nozzle design, air flow patterns, exhaust stack damper settings, and blower speeds on dryer efficiency will be greatly

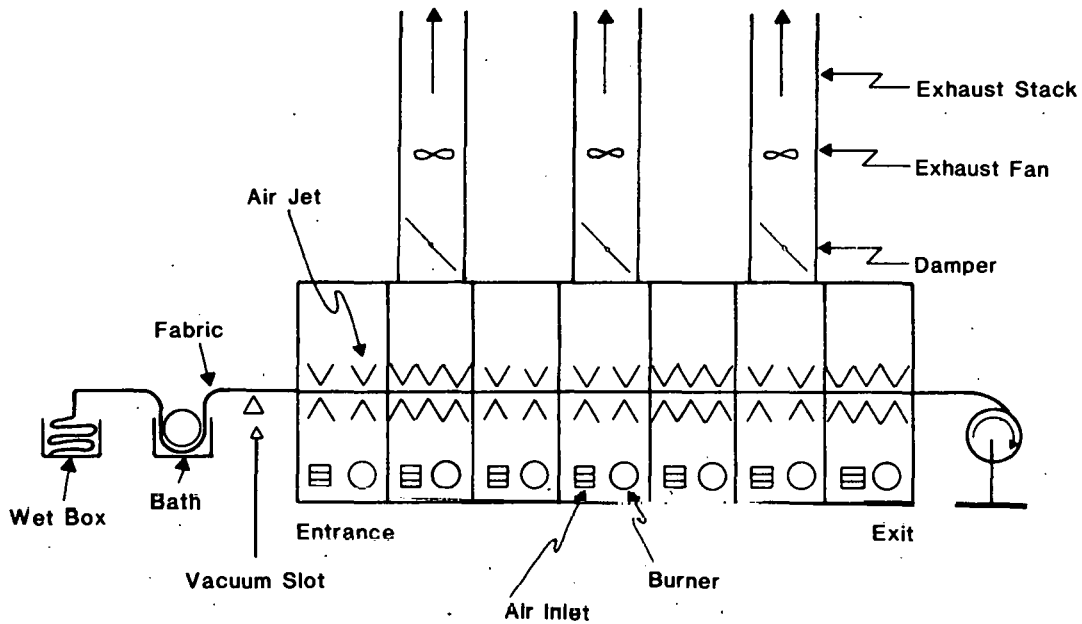


Fig. 3.2 Sketch of a Typical Tenter Frame Dryer
(Source: Ref. 49)

simplified. Moreover, these results will lead to the development of efficiency criteria that the textile industry can use to evaluate dryer performance prior to purchase. The first drying model is currently being used by the textile industry. Information on this model and on an improved form of this model can be found in Ref. 7.

3.2.6 Cogeneration

Cogeneration is the generation of power in one form from a single fuel source, with the waste from the generating process captured and used either directly or indirectly to generate more power or replace heat or steam that would otherwise be generated separately.

Some of the barriers to implementation of cogeneration are those discussed below:^{48,49}

- Government regulation. The National Energy Act (Public Utilities Regulatory Policies Act, P.L. 95-617) provides that any qualifying cogeneration facility producing 30 MW or greater is subject to utility regulation unless that facility is using only biomass to produce energy. Industry would prefer not to be subject to utility regulation. In addition, industry would not want to invest in cogeneration equipment, which uses gas or oil, and subsequently be required to convert to coal.

- Cogeneration competes with nuclear power. Cogeneration may reduce the need for additional nuclear power capacity; therefore, utilities with investments in nuclear power may not favor cogeneration.
- Financing schemes and efficiency codes and standards for cogeneration have not been developed.
- There may not be any technological advances in cogeneration equipment in the foreseeable future.
- There is concern over whether a cogenerating firm would be in conflict with a local utility's territorial rights.
- The cost of construction for transmission and distribution of excess power generated would be prohibitive in many cases.
- Companies are reluctant to invest in large-scale systems because payback periods are long. Although in the past, the payback period has been too long to justify the expenditure for large-scale cogeneration equipment, small-scale (10 MW or less) equipment is becoming economically feasible with the rising costs of power generation and natural gas.
- Diesel engines, the primary type used in large-scale systems, tend to pollute more than other types of cogeneration equipment and, because they are high-efficiency engines, reduce the amount of waste heat available for space heating and other thermal requirements.
- For small companies, high rates for standby power prohibit cogeneration.

3.3 ENVIRONMENTAL/REGULATORY BARRIERS

The major regulatory area in which the textile industry has experienced conflict with energy conservation is compliance with regulations, primarily environmental.³ Compliance with environmental regulations requires a commitment of capital, which otherwise could be committed to energy conservation expenditures. Occupational Safety and Health Administration (OSHA) regulations also are considered by many textile firms to conflict with energy conservation.³ Because several regulatory standards have not yet been promulgated, there is a great deal of uncertainty regarding the investment that will be required to ensure compliance with health and environmental standards.

Sections 3.3.1 and 3.3.2 are discussions of environmental and health and safety considerations associated with the manufacture of textiles, and Sec. 3.3.3 is a discussion of the uncertainties involved in the regulatory standards yet to be promulgated.

3.3.1 Environmental Considerations of Textile Manufacture

Environmental and health/safety standards at both the state and federal level can have a positive or negative impact on the commercialization

potential of a new energy-conserving technology. Such standards can result in either an increase or decrease in energy use and energy efficiency. Often the standards result in increased process efficiency and lower energy use, but, occasionally, compliance with the standards increases energy use. The large amount of capital that industry is currently investing to meet these standards reduces the amount of capital available for the adoption of energy-conserving technologies.

Industrial waste may be categorized as heat or as process residues. Both types are regulated by state and federal governments, and any industrial energy-conserving process change would have to satisfy both federal and state environmental regulations. While states retain primary responsibility, they must do so within a specific federal framework. If a state cannot or does not choose to establish programs meeting federal requirements, the federal government then assumes the responsibility for standard setting. Thus, the environmental standards that must be met by any new technology are promulgated by the responsible state and federal agencies on the basis of the framework set up by the Clean Air Act and the National Primary and Secondary Ambient Standards for New Source Performance for air pollution; the Federal Water Pollution Control Act Amendments of 1972; EPA Best Available Control Technology Economically Available effluent limitation guidelines; and New Source Performance Standards for water pollution; and various nonspecific regulations for the handling and disposal of solid wastes. These regulations are detailed on an industry-by-industry basis in the Federal Register and compiled each year in the Code of Federal Regulations, Title 40, Vols 1-5. Detailed supporting information can be found in a series of EPA documents entitled *Development Documents for Effluent Limitation Guidelines and New Source Performance Standards*, and *Survey Reports on Atmospheric Emissions*.

Given existing environmental regulations, some or all of the following parameters must be considered by an industry evaluating a new technology:

Air pollution

Sulfur oxides
Nitric oxides
Carbon monoxide
Particulates
Photochemical oxidants
Hydrocarbons
Trace metals
Odor
Fugitive emissions
Aldehydes
Ammonia
Chlorine
Hydrogen fluoride
Dust

Water pollution

pH
Total suspended solids
Biological oxygen demand
Chemical oxygen demand
Color and turbidity
Fluorides
Heavy metals
Entrained hydrocarbons
Phosphates
Oil and grease
Carcinogens
Toxic substances

Some energy-conserving processes have environmental benefits. A process that conserves water (and thus the energy required for pumping, heating, and treatment) also reduces the amount of water polluted and the costs of pollution control. One area, however, where energy-conserving measures can have adverse environmental effects is fuel conversion, such

as switching from natural gas to coal.⁵² Natural gas is a relatively clean fuel, unlike coal, which emits sulfur and other pollutants when burned.

Process water effluent contains a variety of organic and inorganic materials from the chemicals used in processing. These include dyes, dye carriers, detergents, sequestering agents, and dissolved salts. The effluent undergoes biological treatment before discharge, so the effluent is defined in terms of its biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS). The combined untreated waste from knit-fabric finishing mills will generally have BOD of 100 to 500 mg/L, TSS of 40 to 485 mg/L, and COD of 450 to 1500 mg/L. Figure 3.3 is a flow diagram of a typical knit-fabric mill, showing daily effluent streams.⁶

Flue-gas effluents from the hot-air dryer and the heat-set tenter contain only small amounts of pollutants. Some lint particles from both units may be present, and a small amount of organic material from the finishing chemicals will be present in the flue gas effluent from the heat-set tenter.

Processing operations for cotton and polyester/cotton woven fabrics are more complex than for knit fabrics. Figures 3.4 and 3.5 show fabric preparation, and fabric dyeing and finishing, respectively. This separation of processes is logical, because in most mills there is an interruption in processing between the two. The first operation (Fig. 3.4) is sizing (also called slashing) of the warp yarn and then drying in preparation for weaving. Although 100 percent PVA size is shown in the flow diagram and has been demonstrated in industry, much of present-day commercial operation still uses starch size or a mixture of starch and synthetic sizes without recovery or recycle.

After weaving, the cloth is singed by direct contact with a natural gas flame, which removes extended fiber ends protruding from the fabric surface, and is then heat set. The cloth is desized by washing with detergent solution, followed by scouring with caustic, bleaching with hydrogen peroxide, and mercerizing with a stronger caustic solution. Each of these steps has an intermediate wash for the fabric to remove residual chemicals before proceeding to the next operation. The first wash after the mercerizer consists of diluted but relatively clean caustic solution, which is recycled to the caustic scour operation. The fabric is then neutralized and dried to complete the fabric preparation steps. Process water is used in all steps (except the drying steps and weaving operations), and the effluents from the washing steps are combined for treatment in a biological treatment system. Steam heat is used in most of the processing steps, including the drying steps that take place on dry cans. Natural gas is used in the singe and heat-set operations, resulting in a relatively pollution-free flue gas.

After preparation, the sequence of operations (Fig. 3.5) entails dyeing the polyester using a thermosol pad, followed by drying and heat setting. A reactive dye is next used to dye the cotton, followed by washing and then drying over dry cans. Finish is then applied by padding, followed by the final heat-set operation in a tenter frame.

PRODUCTION: 22,000 LB/DAY - 100% POLYESTER DOUBLEKNIT

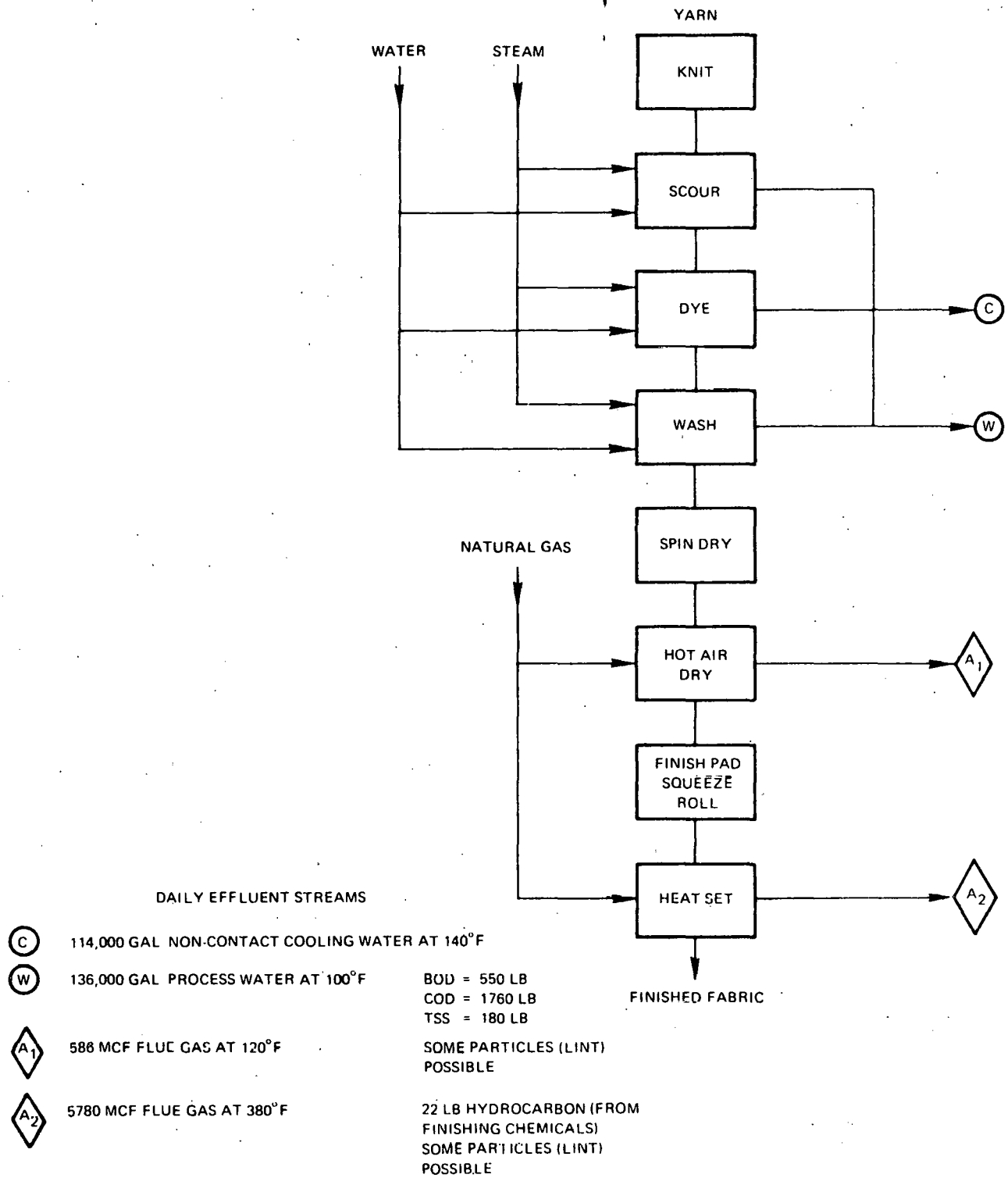


Fig. 3.3 Flow Diagram and Daily Effluent Streams of Typical Knit-Fabric Mill (Source: Ref. 6)

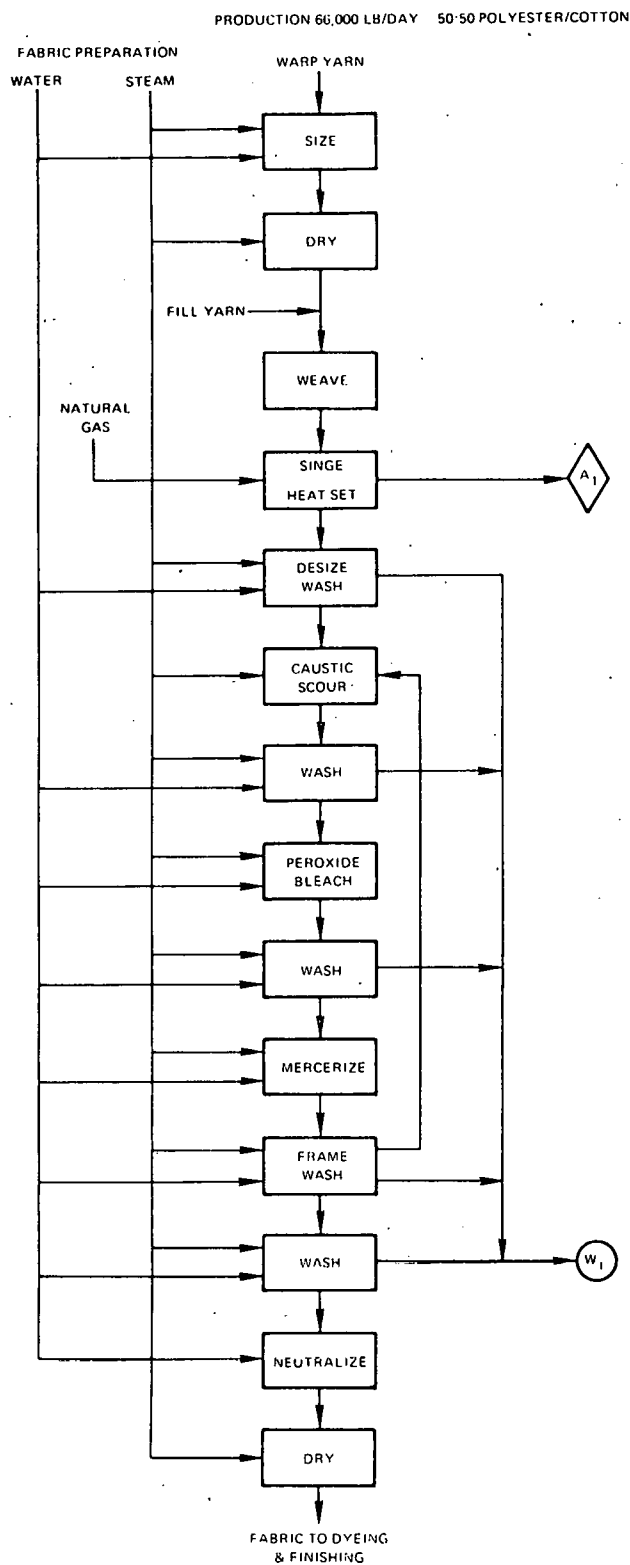


Fig. 3.4 Flow Diagram and Daily Effluent Streams of Fabric Preparation in a Typical Woven-Fabric Mill (Source: Ref. 6)

(PRODUCTION - 66,000 #/day)

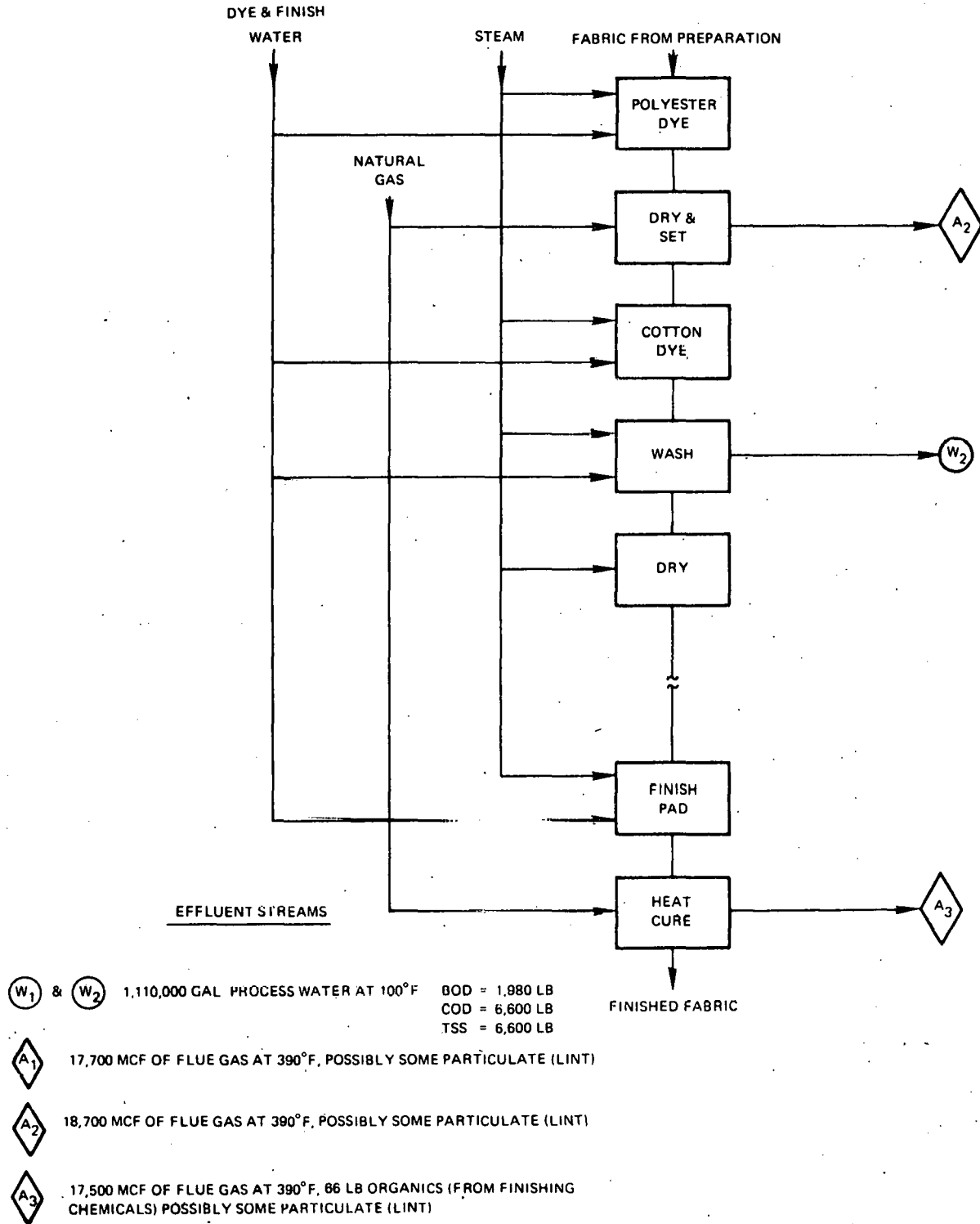


Fig. 3.5 Flow Diagram and Daily Effluent Streams of Dyeing and Finishing in a Typical Woven-Fabric Mill (Source: Ref. 6)

The dry and heat-set operations and the final heat cure require natural gas and result in flue gas effluents to the atmosphere. The washing step after the cotton dyeing produces a wastewater effluent, which is combined with the wastewater effluents from fabric preparation and sent to the biological treatment system. Wastewater from woven-fabric finishing mills contains natural fiber impurities and processing chemicals from desizing, scouring, mercerizing, bleaching, dyeing, and finishing.

The desizing process is a major source of BOD and COD. Desizing waste is also high in dissolved and suspended solids.

Wastewater from scouring and rinsing will contain natural and processing impurities removed by hot alkaline detergents or soap solution used in scouring. The waste will contain significant levels of BOD, dissolved solids, oil and grease, caustic soda, and color.

In mercerizing, the caustic soda absorbed by the cloth is recovered and reused at some large mills. The mercerizing rinse waters are alkaline and high in dissolved solids. Hydrogen peroxide is generally used for bleaching. This process contributes little to the waste load; however, the dissolved solids concentration may be high.

Waste concentrations from dyeing are dependent on the dye and the various other chemicals used. In addition to color, the waste can be high in BOD and dissolved solids.

Finishing chemicals are applied by padding, followed by drying and curing. The chemicals used are diverse, but only small amounts of them will enter the wastewater, as the intent is to capture a very high fraction of the active agent on the cloth.

The combined waste from woven-fabric finishing mills will generally have BOD of 250 to 805 mg/L, TSS of 45 to 475 mg/L, and COD of 425 to 1440 mg/L.⁶

When environmental factors are considered in the evaluation of new energy-conserving technologies, they can be an added benefit rather than a problem, and can provide additional support for the adoption and implementation of energy-conserving measures. A key to effective utilization of industrial energy-conserving technologies is to couple them to pollution control functions within the plant. This requires thorough planning and intensive energy management before the processes are implemented.

3.3.2 Safety and Health Considerations

In addition to environmental factors, other government regulations such as the standards set by the Occupational Safety and Health Administration (OSHA) are a determining factor in decision making. Industrial safety is regulated mainly by the Occupational Safety and Health Act, administered by OSHA. The OSHA regulations are subject to change and must be considered in industry's evaluation of new energy-conserving technologies.²⁴

One health hazard peculiar to the textile industry is byssinosis, sometimes referred to as "brown lung," caused by inhalation of fine cotton dust particles that escape the dust control systems in mills. Symptoms are shortness of breath accompanied by tightness of chest and coughing with a decrease in the ventilatory capacity of the lung. Levels of dust are highest in the parts of the mill where the first operations occur: the opening room, the carding room, and the spinning room.⁵³

3.3.3 Regulatory Standards

The promulgation of several regulatory standards leaves a great deal of uncertainty in the textile industry regarding investments in energy-conserving technologies. The effects of these standards on the textile industry are discussed below.

- Cotton dust standards. It is felt by many industry experts that the engineering standards set by OSHA will be very difficult to achieve economically and that meeting such standards could cost up to \$2 billion in investment costs over the next few years.^{2,54}
- Water pollution standards. Meeting increased standards could cost up to \$1 billion in investment, plus additional costs for cleanup.^{2,54}
- Noise standards. Looms presently in use operate at about 92 dB. It might be possible for the industry to meet a standard of perhaps 91 dB with modifications to existing looms, but to meet more stringent standards could mean replacement of all looms in the industry. It is estimated that \$3-14 billion could be required to meet more stringent standards of 85 dB.^{2,54}
- Air emission standards. Textile finishers will be affected by these standards, primarily because of emissions from tenter frame dryers.^{2,54}

The promulgation of all of these standards will have a direct bearing on the willingness of industry to adopt energy-saving technologies. An investment in equipment designed to save energy but without regard to meeting the new standards could be a costly investment. Industry is reluctant to invest in equipment that may need to be replaced or greatly modified to meet new health and environmental standards.

The effect of new regulatory standards will be uneven because of the variety of processes employed by different plants. In addition, there is a variance in the extent to which plants have already invested in pollution and dust abatement equipment.

3.4 INFORMATION DISSEMINATION AND TECHNOLOGY TRANSFER

To maximize energy conservation, it is essential that industries have current information on energy-conserving technologies. Lack of information can act as a barrier, particularly to smaller companies, which may not

have as much contact with information sources. Additionally, small companies may lack the technical expertise (e.g., energy engineers or energy systems managers) to maximize their energy conservation potential.

According to the Lowry survey, the major sources of energy conservation information for the textile industry are trade organizations and journals. The American Textile Manufacturers Institute (ATMI), in particular, is considered by textile companies to be a useful source of information, through programs and meetings.³ For the most part, corporate engineering is not used as a source of information, and although many companies are willing to accept ideas from equipment salesmen, the latter are not considered reliable sources of information because many of them tend to embellish claims for their equipment.³ The survey showed that, as a rule, consultants are not used by the textile industry to provide information or technical expertise. One reason is that many consultants are not familiar with the problems of the textile industry.³ Academic workshops are not considered by some companies to be useful, primarily because academic research generally lags behind industry; the concepts presented are usually already known; and the proffered solutions are generally not practical.³

A list of major trade journals and organizations with a brief descriptions of each is presented in Appendix C.

4 POSSIBLE MEASURES TO ELIMINATE BARRIERS TO THE IMPLEMENTATION OF ENERGY-CONSERVING TECHNOLOGIES

Because the economic issues form the primary barrier to energy conservation in the textile industry, economic incentives -- in particular, tax credits -- must be the major means by which this barrier is overcome. Such credits can help textile firms overcome the payback-period criterion that often prohibits energy conservation expenditures. According to some companies surveyed by Lowry et al.,³ an increase in fossil fuel prices is a second important way in which the adoption of energy-conserving technologies can be encouraged. Other measures that the federal government can take to encourage energy conservation are to sponsor basic research into improved processes and to aid in providing technical expertise and effective dissemination of information. Government sponsorship of in-plant demonstrations and funding of research to formulate effective methods of market penetration of energy-conserving technologies could help to bring about the adoption of technologies now available or ready for demonstration.²⁶

Section 4.1 is a discussion of economic and tax policies that could affect the adoption of energy-conserving technology by the textile industry. Specifically discussed are taxes and tax credits; price regulation; and loans, loan guarantees, and loan subsidies.

Section 4.2 is a discussion of specific energy-conserving technologies recommended for research. In Section 4.3, environmental/regulatory factors are examined, and Sec. 4.4 is a discussion of technology transfer, and the ways in which the government can act to promote the dissemination of information.

4.1 ECONOMIC POLICIES

4.1.1 Taxes and Tax Credits

Tax credits or tax exemptions are designed to accelerate investment in areas in which the government perceives constraints to optimal industrial implementation. A common criticism is that limitation of the items that qualify can easily discourage innovation in other areas. Investment tax credits are most effective in those areas where they cause an investment to become acceptable rather than marginal. A recent study⁵⁴ has shown that rising prices will have a greater impact on the success of commercialization than will small tax credits of 10-15%, and that a tax credit of 25% or more is necessary before impact is noticeable. The impacts of investment tax credits of different sizes are compared in Figs. 4.1 and 4.2. Plunket⁵⁷ states that a discounted cash flow of 20% on a project is needed to justify an energy conservation investment, a 20% investment tax credit could cause a marginal investment to become acceptable, and a 30% credit would cause a marginal investment to become economically attractive. However, the actual impact of any particular tax credit will depend on the discounted cash flow (internal rate of return; see Sec. 3.1.1) acceptable to the company making the decision.

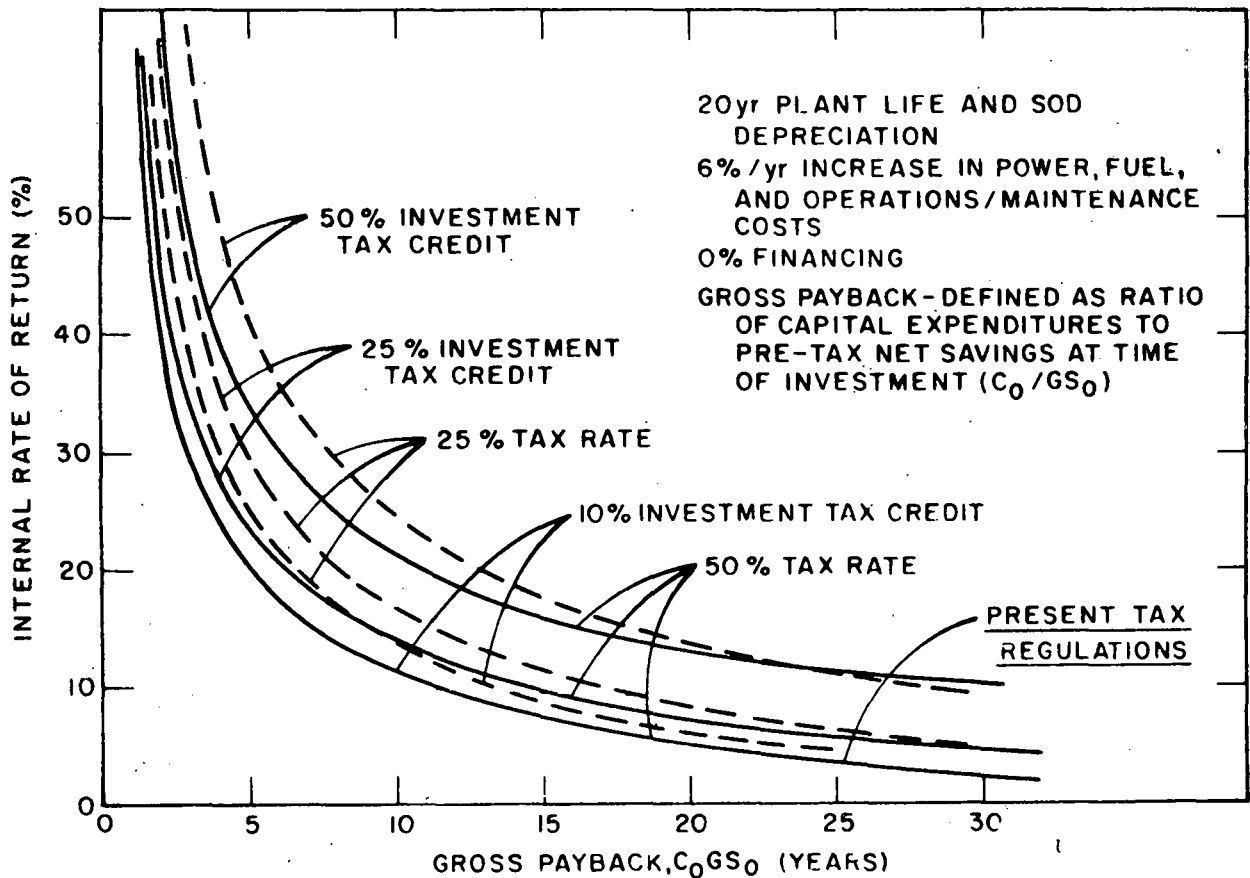


Fig. 4.1 Internal Rate of Return vs. Gross Payback - Effect of Investment Tax Credit and Tax Rate (Source: Ref. 56)

The general investment tax credit is 10% through 1980. The Energy Tax Act of 1978 (P.L. 95-618) provides an additional 10% for certain investments to improve energy efficiency and to use renewable resources.

Changes in the tax regulations themselves can take many forms with varying degrees of effectiveness. Among the more common are:

- Depreciation methods and allowances
- Rapid writeoffs and amortization
- Net operating loss carry forwards and backwards
- R&D expensing allowances
- Capital gain/loss provisions
- Special tax provisions for items such as patent sales

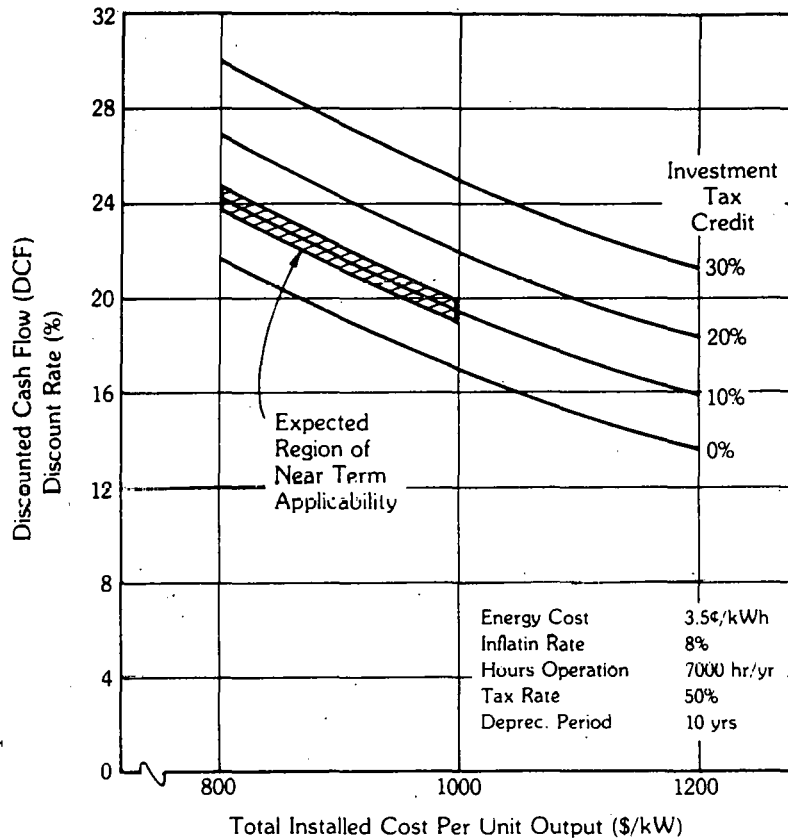


Fig. 4.2 Effect of Investment Tax Credit Rate on the Discounted Cash Flow
(Source: Ref. 57)

Taxes can either encourage innovation in a positive way or eliminate disincentives or barriers. The 1979 federal income tax rate* for U.S. corporations was as follows:

<u>Taxable Income</u>	<u>Tax</u>
Up to \$25,000	17%
\$25,000 - 50,000	\$4,250 + 20% of amount over \$25,000
\$50,000 - 75,000	\$9,250 + 30% of amount over \$50,000
\$75,000 - 100,000	\$16,750 + 40% of amount over \$75,000
\$100,000 or more	\$26,750 + 46% of amount over \$100,000

*From 1979 U.S. Master Tax Guide.

There may also be state taxes, depending on the particular situation. In most cases, income tax rates do not appear to be an appropriate means of influencing specific investments but can be effective for overall economic stimulation. As shown in Fig. 4.3, a change of 4 points in the tax rates produces a 2-point change in the discounted cash flow, and so it is not an effective stimulant for investment specifically in energy-saving equipment. However, changes in certain provisions for calculating industrial taxes could be more effective in stimulating specific types of investments including those in energy conservation.

For example, many people feel that the current tax laws are confiscatory with regard to depreciation of assets and under conditions of high inflation. This could be changed by modifying the schedule for allocating depreciation over the allowable life of the equipment to defer taxes to later years because of the time value of money, reducing the federal profits tax, or permitting a rapid write-off of energy conservation equipment by reducing the depreciation period.

Figure 4.4 compares the effect of different depreciation periods on the discounted cash flow for waste heat recovery projects. It shows that the discounted cash flow or internal rate of return is higher for shorter depreciation periods. Table 4.1 shows, at different discount rates, the tax credits needed to produce the same increase in discounted cash flow as that

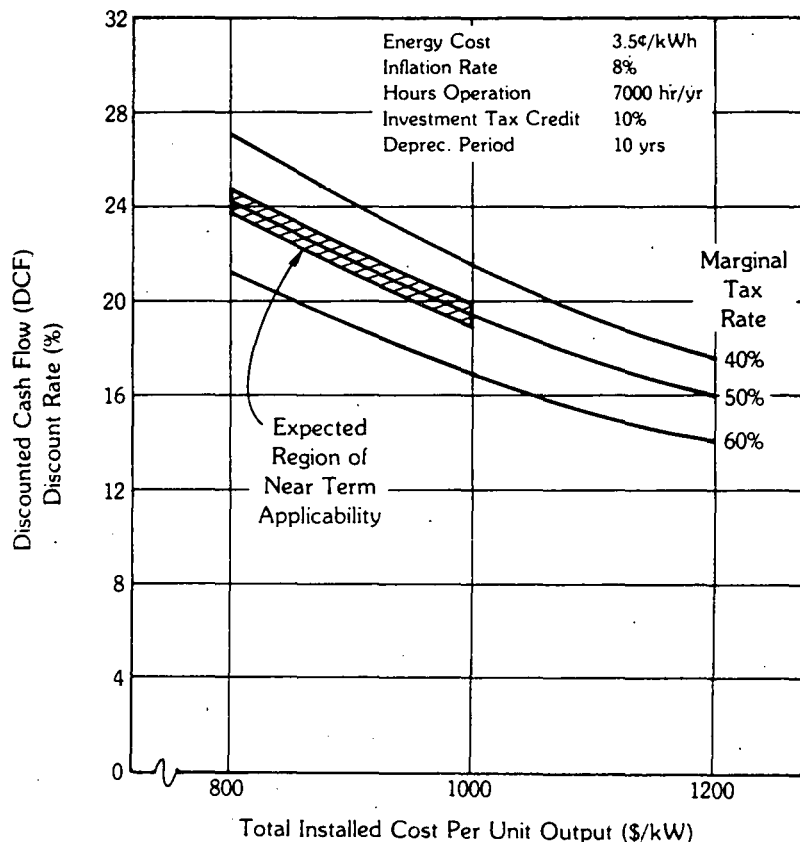


Fig. 4.3 Effect of Marginal Tax Rate on the Discounted Cash Flow (Source: Ref. 57)

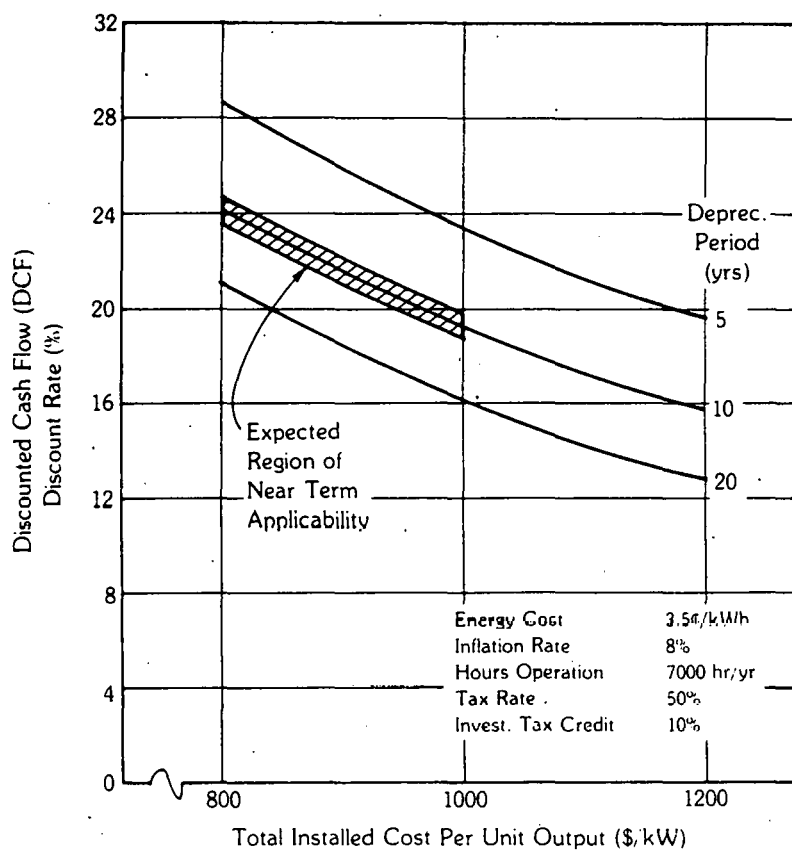


Fig. 4.4 Effect of Depreciation Period on the Discounted Cash Flow (Source: Ref. 57)

Table 4.1 Tax Credits and Corresponding Periods of Accelerated Depreciation, at Various Discount Rates^a

Years of Accelerated Depreciation	Tax Credits (%)		
	Rate of Discount for Computing Present Value		
	10%	12%	15%
2 years	13.93	15.62	17.86
2 1/2 years	12.65	14.18	16.10
3 years	11.80	13.18	14.90
4 years	9.80	10.88	12.18
5 years	7.90	8.73	9.70

^aBased on pre-1979 corporate tax rate of 48%.

Source: Ref. 55.

produced by the corresponding depreciation period. What must be remembered is that even though the aggregate benefits and costs would be the same, the distribution of benefits would be different. Accelerated depreciation is more beneficial to small firms, with their higher cost of capital and higher discount rates, than to larger firms. Such differences in benefit distribution must be considered when alternative incentives are being evaluated.

Tax provisions related to capital gains and losses must also be considered because under current regulations the effective tax rate on highly variable income streams is higher than that on constant income streams. Changes in provisions for net operating loss carry forwards and backwards (excess of allowable deductions over gross income or profits) can significantly affect the financial situation of a firm with regard to investment in a particular product. Of particular interest to small firms are changes in the allowable time periods for such losses (currently seven years) and liberalization of stock options entitled to capital gains treatment. Additional incentives are provided by treating the sale or exchange of patents as long-term capital gains and allowing the expensing of research and development costs to maximize deductions for the firm involved. Such changes seem most attractive for large firms and industries.

4.1.2 Price Regulation

One form of economic regulation is the setting of prices. Examples of this type of regulation at the federal level include the establishment of ceiling prices for domestic "old" and "new" crude oil by the Federal Energy Agency, the well-head price of natural gas by the Federal Power Commission, and airline, rail, and motor transport fares by the Civil Aeronautics Board and the Interstate Commerce Commission. The impact of such price regulation depends on the particular technology and circumstances involved. In the past, conservation technology has been at a strong disadvantage because of artificially low gas and oil prices resulting from federal regulations. Price regulations indirectly affect the attractiveness of investing in new energy-conserving technologies, but in some cases the actual price of a final product is regulated, which reduces the economic attractiveness and potential profitability of the product. This is particularly important for new products, in which case prevailing (first-of-a-kind) costs may be non-recoverable.

4.1.3 Loans, Loan Guarantees, Loan Subsidies

One economic policy available to the government for accelerating the commercialization of new energy conserving technologies is the use of loans, loan guarantees, and loan subsidies to remove some of the capital availability barriers to such investments. Loan guarantees and subsidies are the preferred policies, and direct loans are usually used only as a last resort by the government. Various aspects of these programs are compared in Table 4.2.⁵⁸

The most popular programs in recent years have been loan guarantee programs designed to encourage the private sector to participate in the development of alternative energy sources and the conservation of energy.

Table 4.2 Federal Loan Policies for Financing Desirable Programs

Finance Policies	Policy Component Assumptions	Comparative Characteristics				
		Administrative Requirements	Timing of Expenditures	Degree of Risk Assumed by Gov't	Advantage to Building Owner	Precedents
Direct Loan	50% loan 7% interest 10 years	High -- staff and operation expenses required for loan dispensation and collection.	Total amount provided at one time.	High -- gov't assumes complete risk; responsible for handling defaults and foreclosures.	Would lend at attractive terms directly to building owners for conservation technology.	SBA ^a provides loans up to \$500,000 as last resort if loan is unattainable from bank (for same purposes described under loan guarantee). Interest rate is 6-5/8% at present. Previously, Treasury Department loans at 3% interest were available for low-income housing developers.
Loan Guarantee	90% loan 7% interest 10 years	Moderate -- staff and operation expenses mainly required prior to granting guarantee; closing costs only in cases of default and foreclosure.	Loan payments assumed by gov't only at time of default by owner.	High -- gov't assumes complete risk, but does not have administrative problems associated with default.	Same advantage to owner as direct loan.	SBA provides 90% loan guarantees for businesses economically injured by EPA pollution controls requirements. No limit on loan amount, but maximum interest rate currently at 10-1/2%. HUD ^b previously guaranteed loans for 80% of land acquisition, plus 90% of development costs, for new communities program.
Loan (Interest) Subsidy	90% loan 7% interest 10 years	Minimal -- staff and operation expenses incurred within existing federal lending structure.	Subsidy payments made monthly over life of the loan.	Moderate -- gov't assumes risk only for subsidized part of loan.	Provides potential tax shelter for high tax bracket investors, depending on market rate differential.	HUD has subsidized interest rates (amounting to a loan subsidy) through several programs, including sections 235 (homeowners), and 236 (low-income apartment developers).
Tax Credit	15% income tax credit	None beyond existing IRS audit requirements.	Gov't assumes entire expense via lost tax revenues in one year.	None.	Provides immediate tax benefit of reducing taxable income by full amount the first year.	IRS ^c code provides deductions in taxable income for various investments, including structural improvements for mines and oil and gas wells.
Rapid Write-off	3-yr straight time	None beyond existing IRS audit requirements.	Gov't assumes expense via lost tax revenues over a 3-yr period.	None.	Provides almost the same tax benefit of a credit but spreads the deduction over 3 years, which is still a more rapid depreciation rate than that allowed for any other purpose.	IRS code provides an accelerated write-off or depreciation for equipment which is used for purposes such as pollution control, mine safety, etc. Minimum useful life allowed for certain equipment is 60 months.

^aSBA = Small Business Administration; ^bHUD = Department of Housing and Urban Development; ^cIRS = Internal Revenue Service; Source: Ref. 57.

The purpose of such programs is to provide incentives to lenders to make funds available to industry for energy conservation ventures. It is intended that such financing be available on a long-term basis with terms and conditions and at interest rates comparable to those available to the most favored customers of lending institutions. To mitigate the risk of default and liquidity risks to lenders, two types of federal loan guarantees are generally favored: (1) a government agreement to pay off the loan if the borrower defaults and (2) a government agreement to buy the balance of the loan at any time the lender requests.⁵⁹

The Department of Energy is continuing many of the energy-related loan guarantee and interest assistance programs originally authorized under the U.S. Energy Research and Development Administration (ERDA). The common thread through these programs is the goal of developing normal borrower-lender relationships that encourage the private flow of credit to assist commercial development without the need of continued federal assistance and of promoting maximum participation by the private sector. The major differences between the DOE programs and other federal loan guarantee programs (Small Business Administration, Federal Housing Administration, Farmers Home Administration) are that the latter programs are designed to continue indefinitely into the future and have a high degree of repetitiveness in the type of transactions handled, permitting standardization of processing procedures within the lending institutions involved.⁶⁰

The exact terms of loan guarantees vary from program to program but generally finance 75-90% of the total cost of the investment for a period of 55 years at the prevailing interest rates in the private market for similar loans and risks. Guarantees can either be on a project-by-project basis or for all qualified applications (blanket approach). The major sources of the funds for these programs are banks, pension trusts, life insurance companies, and bonds sold to the general public. These funding sources are attractive to the government because they allow nonbudget financing of desirable programs. Although administrative expenses for these programs have been high, they are small relative to the total volume of private loans that have been guaranteed. These programs have been found to be most effective for fragmented industries and small firms.

4.2. TECHNOLOGICAL MEASURES

One major step toward increased energy conservation that could be taken by even the smallest company is an energy audit. Such audits could be partially funded by federal or state governments, or through other institutional arrangements. For example, in 1978, the Texas Industrial Commission provided assistance to industries as part of the state's energy conservation program.¹⁹ The energy audit program was designed to help small and low-technology firms reduce energy consumption. Under the program, the Commission paid contracted engineering consultants 5% of each plant's total energy bill for 1977 (not to exceed \$4,000 for each audit) plus \$1,400 for a manual developed by the consultants.

Another example of aid to energy audits is that provided by the Southern California Gas Co. The company provides on-site energy audits by a van equipped with a computer and energy efficiency test equipment.⁶¹

Combustion analyses are conducted and the computer calculates costs and payback period for new energy-related equipment. Audits are free to industrial customers.

Along these same lines, plant inspections by trained specialists could be useful in developing varying combinations of new energy-conserving equipment and modifications to operations. Such a team from the Georgia Institute of Technology provided this service to several firms in Georgia, with good results. Most firms were receptive and cooperative, and the Georgia Tech team was able to identify significant opportunities for energy savings, in most cases with concurrent savings in operating costs.¹⁰

Specific research recommended to aid in the adoption of energy-conserving technology by the textile industry is discussed below. In addition to funding of research, funding of in-plant demonstrations (including economics) would do much toward bringing about the adoption of energy-conserving technologies.²⁶

Unless otherwise indicated, the specific research discussed below is that recommended at the Department of Energy Workshop on Energy Conservation in the Textile Industry.¹⁸ Table 4.3 lists these technologies and their priorities; costs; estimated energy savings; time frame for research, development, and demonstration; the extent of federal involvement in the development of the technologies; and possible barriers to their commercialization.

- Economic filtration system for heat recovery units. The system should aid in the recovery of reusable materials and should clean easily, with a minimum of downtime.
- Compact, economical cogeneration system. Guidelines should be developed for a system to generate steam and electricity. The system should operate with no condensing equipment and should generate 1500 kW (50,000 lb/hr of steam) at a target price in 1977 dollars of \$100/kW.
- Energy analyses of all textile processes. Areas of high energy consumption in mills should be identified, and energy profiles of those areas should be formulated. Approaches to energy reduction should be recommended.
- Economical coal-burning boiler. The unit should be a package unit, with a steam generation range of 5,000-100,000 lb/hr, and must meet EPA requirements.
- Improved drying technology. Dryer designs should be optimized; parameters should include circulated air volume, temperature, exhaust volume, and nozzle design. Sensing of dew-point for exhaust control state-of-the-art should be surveyed. A study has been initiated by Argonne National Laboratory to develop an in situ moisture content monitor for the textile fabric drying process and to demonstrate the feasibility of computerizing the fabric drying process using the moisture content sensor as feedback.

Table 4.3 Technologies Recommended for Research at the DOE Workshop on Energy Conservation in the Textile Industry

Project	Priority	Estimated Energy Conserved Annually	Time Frame			Cost			Federal Role (%)			Probability of Implementation	Barriers to Commercialization
			Res.	Devel.	Demo.	Res.	Devel.	Demo.	Res.	Devel.	Demo.		
Heat recovery of contaminated exhausts	High	25% of dryer energy consumption	2 yr	1 yr	1 yr				100	75	50	Good	Practicability, cost
Development of cogeneration system	High	30% of mill electric demand		2 yr	2 yr		\$1,000,000	\$500,000		50	50	Good	System cost
Energy analysis of textile processes	High		3-5 yr			3 man-yr/yr			100			Good if savings are appreciable	
Development of coal boiler	High	Not applicable	1 yr	2 yr	2 yr	2 man-yr	10 man-yr/yr	\$3,500,000	100	100	75	Good	Capital and operating costs
Improvement of drying technology	High	20% of drying energy	1 yr	2 yr	1 yr	4 man-yr	\$250,000	\$150,000	100	75	75	Good	Reliability and maintenance
Moisture analyzer	1	0.0025 quad	2 yr	1 yr	1 yr	\$180,000	\$90,000	\$90,000	85	85	0	Good	Limited potential market may be insufficient to offset developmental costs
Exhaust gas incineration	2	1.1×10^{13} Btu	1 yr			\$250,000			100	100	20		Possible boiler control performance
Pad/batch preparation and drying	3	0.0033 quad	2 yr	2 yr	1 yr	\$250,000	\$250,000	\$500,000	80	60	50		Displacement of heavy existing capital investment
Energy optimization in textile scouring	4	0.0576 quad	2 yr	2 yr	1 yr	\$500,000	\$500,000	\$1,000,000	100	80	60	Good	
Energy-efficient moisture removal systems	5	10-25% of energy consumed for moisture removal (8.6×10^6 BOE ^a)	2 yr	1 yr	1 yr	\$200,000	\$100,000	\$200,000	100	90	50	Good	Capital equipment costs

Table 4.3 (Cont'd)

Project	Priority	Estimated Energy Conserved Annually	Time Frame			Cost			Federal Role (%)			Probability of Implementation	Barriers to Commercialization
			Res.	Devel.	Demo.	Res.	Devel.	Demo.	Res.	Devel.	Demo.		
Cleaning of exhaust emissions for heat recovery	6	7.1×10^{12} Btu	1 yr	1 yr	1 yr	\$50,000	\$50,000	\$200,000	100	100	50	Good	
Direct application of process chemicals	7	0.4×10^6 BOE	4 yr	2 yr	1 yr	\$400,000	\$200,000	\$200,000	100	80	50	Fair	Capital equipment costs
Low-energy continuous dye systems	8	0.0268 quad	2 yr	1 yr	1 yr	\$500,000	\$500,000	\$1,000,000	80	65	50	Good	Capital investment for new equipment
Sludge incineration	9	1.4×10^{12} Btu		2 yr						100	20	Fair	Initial cost, handling, and municipal laws
Anaerobic digestion of sludge	9	1.5×10^{12} Btu		2 yr			\$500,000			100	100	Fair	Initial cost, handling, and municipal laws
State-of-the-art review of literature	High	2.5×10^9 kWh	1 yr						100				Review needs to be prepared in form meaningful to operating personnel
Exhaust gas incineration	2	1.1×10^{13} Btu	1 yr			\$250,000			100	100	20		Possible boiler control performance
Power measurement equipment	Medium	None directly; would permit completion of other projects	1 yr	1 yr	1 yr	\$50,000	\$150,000	\$50,000	100	100	100		Instrumentation cost
Energy conservation in weaving	Medium	0.8×10^9 kWh	1 yr	1 yr	1 yr	\$60,000	\$60,000	\$60,000	100	100	100	Good	
Energy conservation in texturing	Medium	1.8×10^9 kWh	1 yr	1 yr	1 yr	\$50,000	\$80,000	\$80,000	100	100	100	Good	

Table 4.3 (Cont'd)

Project	Priority	Estimated Energy Conserved Annually	Time Frame			Cost			Federal Role (%)			Probability of Implementation	Barriers to Commercialization
			Res.	Devel.	Demo.	Res.	Devel.	Demo.	Res.	Devel.	Demo.		
Energy conservation in yarn forming and preparation	High	2.0 x 10 ⁹ kWh	1 yr	1 yr	1 yr	\$60,000	\$70,000	\$100,000	100	100	90	Good	
Low-energy sizing	High	4.0 x 10 ⁹ kWh	2 yr	3 yr	2 yr	\$250,000	\$500,000	\$300,000	100	100	80	Good	Process acceptability
Curriculum for fixers and changers	High			2 yr	1 yr		\$100,000	\$537,000		100	80	Good	
Electrostatic waste removal	High						\$85,000	\$15,000					
Computer model of energy needs of a mill	Medium	107 kWh	6 mo	1 yr	6 mo	\$25,000	\$50,000	\$25,000	100	100	100	Good	
Optimizing power needs of greige mill	High	675 x 10 ⁶ kWh		1 yr			\$250,000			75		Good	Dissemination of information
Energy conservation via lubricants	Medium	5% of textile mill energy use	1 yr	1 yr	1 yr	\$50,000	\$100,000	\$50,000	100	100	80	Fair	Resistance to use of unknown product to save energy
Tuft to yarn system	High		3 yr	2 yr	1 yr								Overall system would be a revolutionary change in yarn production. Phases of the system could be introduced into present processing lines
Electrostatic spinning	Medium	30% of energy used by present equipment	3 yr	2 yr	1 yr								Life of present spinning equipment
Low-temperature curing	High	0.6-0.8 x 10 ⁶ BOE	2 yr	1 yr	1 yr	\$320,000	\$160,000	\$100,000	75	75	50	Good	

Table 4.3 (Cont'd)

Project	Priority	Estimated Energy Conserved Annually	Time Frame			Cost			Federal Role (%)			Probability of Implementation	Barriers to Commercialization
			Res.	Devel.	Demo.	Res.	Devel.	Demo.	Res.	Devel.	Demo.		
Optimization of drying techniques	High	2.5-5 x 10 ⁶ BOE	1 yr	1 yr	1 yr	\$75,000	\$75,000	\$75,000	95	95	95	Good	
Metering techniques for finishing agents	High	2.25-3 x 10 ⁶ BOE	1 yr	2 yr	1 yr	\$80,000	\$400,000	\$100,000	75	75	50	Good	
Exhaust incineration	High	1.2 x 10 ⁶ BOE	1 yr	1 yr	1 yr	\$500,000	\$500,000	\$500,000	100	75	50	Good	Capital cost
Effluent neutralization via flue gases	Medium	0.4 x 10 ⁶ BOE	2 yr	2 yr	2 yr	\$500,000	\$500,000	\$1,500,000	100	75	50	Good	Capital costs, materials, and maintenance
Development of new size	Medium	1200-1600 Btu/lb	3 yr	1-2 yr									
Study of Machnozzle	Medium	2.5-3.5 x 10 ⁶ BOE	1 yr	1 yr	1 yr	\$50,000	\$25,000	\$25,000	100	100	50	Good	
Radiation curing	Medium	9 x 10 ⁶ BOE	2 yr	1 yr	1 yr	\$170,000	\$800,000	\$800,000	80	65	65	Good	Capital cost
Systems analysis of a finishing plant	Medium					\$100,000						Good	
New bleaching technology	Medium	0.46 x 10 ⁶ BOE	1 yr	1 yr	1 yr	\$150,000	\$100,000	\$100,000	70	60	50	Good	
Alternate fuels for finishing	Medium												
Microwave or dielectric heating	Low												
Modification of steam can technology	Low												
Flame curing finishes	Very Low												

^aBOE = Barrels of Oil Equivalent.

Source: Ref. 12.

- Low-cost instrumentation for measurement of moisture and humidity. Current technology exhibits a lack of accurate measurement and recording instrumentation for determining residual moisture content in fabrics following continuous drying. Consequently, fabrics are frequently overdried. In addition, technology and necessary instrumentation are not available to measure humidity content in exhaust gases at high temperatures. The lack of this instrumentation results in large heat losses because of excessive flow of exhaust air.
- Exhaust gas incineration of dryer and curer emissions. A feasibility study should be conducted, and an evaluation made of the possible incineration of exhaust stack emissions from tenters, curers, and dryers via the plant boiler. The energy conserved is the amount exceeding that thought to be available under present techniques.
- Pad/batch preparation and dyeing. The pad/batch method allows low-temperature treatment and a more energy-efficient means of preparing and dyeing fabric than do conventional processes. Feasibility of the concept has been demonstrated on cellulose with energy savings up to 60% and water savings up to 90% reported over conventional cellulose batch dyeing processes. This process, or a modification of it, needs to be extended to synthetics and blends.
- Energy optimization in textile scouring. The efficiency and energy use of various scouring processes should be evaluated. The study should include analyses of continuous, batch, counterflow, spray, foam, and other innovative scouring techniques. The analysis should evaluate mechanical and chemical systems for scouring and should determine methods for identifying the optimum end point for scouring. This could be a multiphase project. Current technology on some phases could be demonstrated immediately. Other phases would require more research and development.
- Energy-efficient moisture removal systems. A study should be made of all possible processes and combinations of processes by which moisture can be removed from materials at low or ambient temperatures. Recommended goals in moisture removal should be set as follows:

<u>Process</u>	<u>Moisture Content (%)</u>
Wet-on-wet processing	
100% cotton	30
Polyester-cotton blends	15
Predrying	
100% cotton	60
Polyester-cotton blends	30
Drying	
100% cotton	10
Polyester-cotton blends	5

Some new or improved technologies that should be considered include: the Machnozzle, microwave technology, ultrasonic technology, and moisture-removing rolls and felts (including new developments in moisture-absorbing fiber systems, i.e., "super slurpers"). Efficiencies of moisture removal over various ranges of moisture content should be evaluated. In some cases, it may be necessary to combine technologies. Systems for moisture removal must not inhibit production rates, and must take into account migration problems during predrying.

- Cleaning exhaust emissions from dryers, curers, tenters for optimum heat recovery. A study should be conducted to determine the most efficient and cost-effective means of cleaning exhaust emissions from tenters, dryers, and curers in order to realize optimum heat recovery from such emissions.
- Direct application of process chemicals to fibers and fabrics. Techniques should be developed for the application of process chemicals to textile products with minimum use of liquid media. Such techniques would reduce or eliminate intermediate washing and drying steps and would minimize energy requirements in final drying. The following techniques may be promising:

Electrostatic deposition of dyes

Gaseous reactants in preparation (e.g., ozone, singlet oxygen)

Vapor phase reactants

Spray application of reactants

Machine development to reduce wet pickup

These techniques must permit treating of fiber and fabrics uniformly or in a controlled pattern, in a way that can be adopted by the textile industry.

- Development of low-energy continuous dye systems. Continuous dyeing requires less energy than batch dyeing (e.g., continuous dyeing of cellulose requires 20% of the energy required for batch dyeing). Presently, continuous dyeing is limited by the economic requirement that extremely long yardage of the same shade is necessary. Continuous dyeing can be made more universal if systems are developed for economical continuous dyeing of short yardages. Use of computer color measurement systems, which are already on-line, will optimize color control and substantially reduce the risk of failure on short runs. Development of computer color measurement systems for short yardages would be a part of this project.

- Disposal of sludge from a waste treatment plant via incineration. An evaluation should be made of the disposal of sludge and mill wastes by incineration. A waste heat boiler would be used in this scheme to produce steam for process heat.
- Disposal of sludge from a waste treatment plant by aerobic digestion. An evaluation should be conducted of the generation of methane from waste and sludge outputs of textile mills. Pelletizing of solid fuel from the remaining waste products would be examined.
- Spinning and weaving equipment:

State-of-the-art review of the literature on energy consumption and conservation in textile manufacturing.

Development of instrumentation and techniques for measuring the performance of various pieces of equipment (e.g., looms). Studies are also needed on energy conservation in weaving, texturizing, yarn forming, and preparation. The objective should be first to identify main energy-consuming mechanisms; the focus should subsequently be shifted to increasing energy efficiency.

Projects in low-energy sizing, including studies of form and dry sizing, and training programs for mechanics and fixers to encourage awareness of energy efficiency and energy conservation should be developed.

Electrostatic waste removal, development of a computer model of energy requirements, study of the possibility of saving energy via improved lubricants and better lubrication techniques, and optimization of power requirements for air-conditioning in greige mills (25-30% of energy consumed in a greige mill is for air-conditioning and air handling).

- Advanced aqueous and all-solvent processing.⁶

PVA recovery has been shown to have economic and energy-conserving advantages. So far, however, this has only been demonstrated on polyester/cotton sheeting. Its applicability to other products and fibers should be demonstrated.

Energy saving is possible if the amount of water used for washing can be reduced substantially. This requires an evaluation of washing efficiency for the various types of washers currently used in the industry and for the new units now available. Concurrent with this, there should be a program to demonstrate improved instrumentation and techniques for monitoring washing in the various process steps and to determine when adequate washing has been achieved.

Water reuse currently appears to be limited by the variety of chemicals used in each process step. Development work could minimize the amount of chemical used in each step and make the different chemicals more compatible with each other, so that processing steps might be combined and/or additional water recycled.

Recovery of chemicals other than PVA and caustic soda has not yet achieved any major application, although work is in progress to evaluate the reuse of water and chemicals in dyeing operations. Additional methods for recovery of dyes (high-cost chemicals that cause color problems in waste treatment plants because of their refractory nature) should be investigated.

A major obstacle to the demonstration of an all-solvent processing system is the lack of acceptable techniques for solvent dyeing, particularly of polyester and cotton/polyester blends. Pilot-scale studies should be carried out to demonstrate the advantages and limitations of the best processes described in the literature. Similar work is also required to demonstrate the applicability of solvent finishing systems.

It appears from the data available that solvent losses from an all-solvent system are now only marginally acceptable and may be in excess of future occupational health or environmental regulations. A study of an all-solvent system is required to define where and how solvent losses occur and to develop better control technology for solvent emissions. Otherwise, this problem may represent an obstacle to further development of solvent processing.

4.3 ENVIRONMENTAL/REGULATORY POLICIES

Compatibility of energy conservation and environmental regulations is important to energy conservation. However, most state and federal health and environmental standards are developed without regard to their energy-conserving effects.²⁴ Without major changes in the planning and coordination of the agencies involved, this is unlikely to change in the foreseeable future.

Many energy-conserving technologies are both economically and environmentally sound. Advanced aqueous and solvent processing are examples of such technologies (see Tables 4.4 through 4.7). The development and application of energy-conserving technologies that are environmentally acceptable should be encouraged.

4.4 INFORMATION DISSEMINATION/TECHNOLOGY TRANSFER

Effective information dissemination and technology transfer is particularly important to small- and medium-sized firms, of which much of the textile industry is composed.

Table 4.4 Summary of Process Options in the Textile Industry
(Baseline Process: Integrated Knit-Fabric Mill)

	Process Options	
	Advanced Processing	Solvent Processing
Economics	Slightly higher capital cost. Marginally lower pollution control costs as a result of reduced process water consumption. Lower energy costs.	Higher capital cost, lower operating cost, lower energy costs (pollution control is an integral part of the solvent recovery system).
Energy	Lower steam and natural gas use. Higher electrical energy use through substitution of mechanical energy for heat energy to remove water. Overall energy saving of 50%.	Lower natural gas use, but higher steam consumption for solvent recovery. Overall decrease of 70% in energy use.
Environmental	No change in feedstock or products. Lower water use allows more effective biological wastewater treatment. Minimal air pollution, no solid waste.	No change in feedstock or products. Eliminates water pollution problems but introduces potential air pollution from chlorinated hydrocarbons. Some solid waste for disposal but lower overall chemical use.

Source: Ref. 6.

In a study recently conducted by Argonne National Laboratory,⁶⁰ several types of organizations were identified as being interested and involved in the dissemination of information on energy conservation. These organizations and a summary of their activities are listed in Table 4.8. As can be seen in the table, both federal and state agencies are involved, as well as utilities, trade associations, professional societies, universities and research institutes, and manufacturers and consultants. Because the textile industry relies on trade organizations and journals (see Appendix C) for energy conservation information, these two sources might serve as a forum for exchanges of generic information and notices of seminars and workshops.

Because the textile industry is concentrated in a three-state region, a regional approach to energy conservation would seem both workable and effective. State agencies could be useful in the development of such an approach. At present, the states are working independently. A cooperative venture between state agencies could reduce duplication of effort and increase program efficiency.

Table 4.5 Comparison of Processes in an Integrated Knit-Fabric Mill
(Production: 22,000 lb/day)

	Baseline Process	Advanced Process	Solvent Process
	(all per 10 ³ lb of production)		
Energy Consumption			
Electricity (10 ⁶ Btu equiv.) ^a	1.9	2.6	1.3
Steam (10 ⁶ Btu equiv.)	8.2	4.1	2.4
Natural gas (10 ⁶ Btu)	4.0	0.4	0.4
Total (10 ⁶ Btu)	14.1	7.1	4.1
Pollution Potential			
Water			
Hydraulic load (gal)	6,190	2,050	-
Pollution loading (BOD lb)	25	25	-
(COD lb)	80	80	-
(TSS lb)	80	80	-
Air	Small	Small	Small
Solid waste	-	-	Small (=100 lb)
Economics (\$)			
Capital investment	2,560	2,650	2,820
Variable costs ^b	1,620	1,610	1,500
Fixed costs	420	430	450
Energy costs	26	13	21
Pollution control costs	26	13	- ^c
Total annual costs ^d	2,450	2,440	2,330

^aElectricity 1 kWh = 10,500 Btu equiv.

^bVariable costs include energy costs.

^cPollution control costs are included in manufacturing costs.

^dTotal annual costs = (fixed costs + variable costs + pollution control costs) x 12.

Source: Ref. 6.

Table 4.6 Comparison of Processes in an Integrated Woven-Fabric Mill
(Production 66,000 lb/day)

	Baseline Process (per 1000 lb of production)	Advanced Process
Energy Consumption		
Electricity (10 ⁶ Btu equiv.) ^a	3.0	1.6
Steam (10 ⁶ Btu equiv.)	32.2	14.4
Natural gas (10 ⁶ Btu)	7.1	3.3
Total (10 ⁶ Btu)	42.3	18.2
Pollution Potential		
Water		
Hydraulic load (gal)	16,800	5,830
Pollution loading (BOD lb)	30	25
(COD lb)	100	50
(TSS lb)	100	100
Air	Small	Small
Solid waste	Small	Small
Economics (\$)		
Capital investment	5,610	5,690
Variable costs	1,480	1,400
Fixed costs	860	860
Energy costs	81	33
Pollution control costs	20	18
Total annual costs ^c	2,810	2,720

^aElectricity 1 kWh = 10,500 Btu equiv.

^bVariable costs include energy costs.

^cTotal annual costs = (fixed costs + variable costs + pollution control costs) x 12.

Source: Ref. 6.

Table 4.7 Summary of Energy Conservation Activities of Various Types of Organizations

Type of Organization	Level of Technology Included	Size of Firms Chosen as Audience	Energy Audits Performed; Level	Conferences Sponsored; Type	Workshops/Seminars Courses Sponsored; Type	Literature Published; Type	Distributed	Library; Accessibility	Referral Service/ Response to Inquiries
Federal agencies	Good housekeeping, off-the-shelf technology - FEA, DOC; new technologies - ERDA	Large in past, now all sizes	Occasional; general and specific	Yes, general and specific	Yes, general and specific	Yes, general and specific	Yes	Yes; public	Depends on agency; mostly yes
State agencies	Good housekeeping, off-the-shelf technology	Small, medium	Occasional; general and specific	Yes, general	Occasional; general	Yes, mostly general, brochures	Yes	Often; public	Depends on state; mostly yes
Trade associations	Good housekeeping, off-the-shelf technology	Starts with large and works down to small	Occasional; specific	Yes, general and specific	Occasional; depends on association involved	Depends on association involved; magazines, brochures	Sometimes	Sometimes; members	Sometimes for members; often have list of manufacturers
Professional societies	Good housekeeping, off-the-shelf technology	Starts with large and works down to small	Seldom	Yes, general and specific	Occasional; depends on society involved	Sometimes; journals, brochures	Sometimes	Sometimes; members	Sometimes, mostly for members; often have list of consultants or members with expertise
Utilities	Good housekeeping, off-the-shelf technology	Large in past, now all sizes	Occasional; basic	Occasional; general	Occasional, general	Yes; general brochures	Yes	No	Sometimes for customers; list of manufacturers and consultants
Universities/ Research Institutes	New technology	Varied	No	Yes, general and specific	Yes, specific	Yes; specific journals, books	Sometimes	Sometimes; students/ researchers	Seldom
Manufacturers/ Consultants	Good housekeeping, off-the-shelf technology	All	Yes, general and specific	No	Occasional	Yes; brochures	Yes	No	No referral service; handle inquiries if it will generate business

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APPENDIX A

FINANCIAL PROFILE OF THE TEXTILE INDUSTRY

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A.1 Production

The principal fabrics produced by the weaving mills are broadwoven fabrics, and over 55% of all broadwoven fabrics produced in 1977 were of man-made fibers.⁴ Broadwoven fabric mills employ 33% of the textile industry work force.⁴ Broadwoven fabric production increased at a moderate rate in the first half of 1977, primarily in cotton and wool fabrics, which reflects the continuing trend in consumer demand for natural fiber fabrics. The 1976 financial profile of the broadwoven fabric industry is presented in Table A.1.

Another principal component of the textile industry is the knit fabric industry; a financial profile of knit fabric mills is shown in Table A.2.

Production of spun sales yarn of cotton, wool, and man-made fibers was 1.7 billion pounds in 1976, an increase of 25% from 1975. Total fiber yarn production increased in 1976; man-made fiber yarn showed the largest increase with more than 40%, and cotton was third with 15%. Yarn mills employ 11% of all textile employees. A profile of yarn mills is presented in Table A.3.

Carpet and rug production increased 10% in 1976, making up the 10% decline of 1975. Total shipments of carpet and rugs in the first quarter of 1977 totaled 224 million yd² compared with 222 million yd² a year earlier. In terms of value, shipments continued to climb but at a slower rate in 1977. Tufted carpets accounted for more than 90% of the total shipments in 1977, with nylon continuing to dominate the market. The growth of polyester has declined slightly due to increasing fiber prices and the higher processing costs associated with polyester. Carpet and rug mills account for 6% of all textile mill employment. The 1976 financial profile of carpet and rug mills is shown in Table A.4.

Table A.1 1976 Profile of the Broadwoven Fabric Industry (SIC Codes 221, 222, 223)

Value of industry shipments	\$10,077 million
Value of shipments/PPI ^a	68
Number of establishments (1974)	930
Total employment	295,000
Exports as a percentage of industry shipments	8.5
Imports as a percentage of apparent consumption	7.3
Compound annual rate of growth 1967-76 (%)	
Value of shipments (current \$)	4.6
Value of exports (current \$)	16.1
Value of imports (current \$)	9.4
Employment	-2.0

^aTo partially compensate for the effects of inflation, the value of shipments was divided by the Producers' Price Index (formerly the Wholesale Price Index).

Source: Ref. 4.

Table A.2 1976 Financial Profile of Knit-Fabric Mills (SIC Codes 2257, 2258)

Value of industry shipments	\$4,565 million
Value of shipments/PPI ^a	31
Number of establishments (1974)	738
Total employment	78,000
Exports as a percentage of industry shipments	1.3
Imports as a percentage of apparent consumption	0.9
Compound annual rate of growth 1967-76 (%)	
Value of shipments (current \$)	14.4
Value of exports (current \$)	11.4
Value of imports (current \$)	12.4
Employment	9.0

^aTo partially compensate for the effects of inflation, the value of shipments was divided by the Producers' Price Index (formerly the Wholesale Price Index).

Source: Ref. 4.

Table A.3 1976 Financial Profile of Yarn Mills (SIC Codes 2281, 2283)

Value of industry shipments	\$3,011 million
Value of shipments/PPI ^a	20
Number of establishments (1974)	511
Total employment	96,000
Exports as a percentage of industry shipments	1.7
Imports as a percentage of apparent consumption	2.3
Compound annual rate of growth 1967-76 (%)	
Value of shipments (current \$)	6.0
Value of exports (current \$)	23.1
Value of imports (current \$)	5.7
Employment	0.7

^aTo partially compensate for the effects of inflation, the value of shipments was divided by the Producers' Price Index (formerly the Wholesale Price Index).

Source: Ref. 4.

Table A.4 1976 Financial Profile of Carpet and
Rug Industry (SIC Code 227)

Value of industry shipments	\$3,553 million
Value of shipments/PPI ^a	24
Number of establishments	522
Total employment	52,000
Exports as a percentage of industry shipments	3.0
Imports as a percentage of apparent consumption	3.4
Compound annual rate of growth 1967-76 (%)	
Value of shipments (current \$)	8.1
Value of exports (current \$)	20.2
Value of imports (current \$)	11.4
Employment	1.9

^aTo partially compensate for the effects of inflation, the value of shipments was divided by the Producers' Price Index (formerly the Wholesale Price Index).

Source: Ref. 4.

A.2 Employment

Employment in the textile industry during 1977 averaged 980,000, up from 897,000 in 1976. About 87% of the employed labor force are production workers, compared with 72% in all manufacturing.⁴

The industry unemployment rate for the first half of 1977 averaged 8%, compared with 9% in 1976 and 14% in 1971. The average unemployment rates for all manufacturing industries were 7% during the first half of 1977 and 8% and 11% for 1976 and 1975, respectively.

Average hourly wages for textile production workers continued to increase in 1977, reflecting wage increases of up to 9% announced by the industry earlier in the year. Hourly earnings for production workers averaged \$3.86 during the first half of 1977, or 43% below the overall manufacturing average for the same period. The 1976 and 1975 average hourly earnings in the industry were \$3.67 and \$3.40, respectively. Payroll costs amount to 53% of the value added in this labor-intensive industry.⁴

A.3 Fiber Consumption and Cost

Textile mill fiber consumption increased to 12.5 billion pounds in 1977, up 8% from 1976. Man-made fibers accounted for more than 70% of all fibers used in 1977, cotton for 29%, and wool fibers for 1%.⁴

Prices for textile mill products, as recorded by the Wholesale Price Index (WPI), rose at an annual rate of 4% in 1977, twice the rate recorded in

1976. Prices of raw cotton remained stable in the first half of 1977 after climbing 50% in 1976 over 1975 levels. Cotton prices declined in the latter part of 1977.

Man-made fiber prices increased at an annual rate of 4% in 1977, twice the rate recorded in 1976. Wholesale prices of domestic wool increased at an annual rate of 6% in 1977 after registering an increase of 29% in 1976.

Man-Made Fibers

Demand for man-made fibers increased moderately in the first half of 1977, paced by upturns in the markets for women's knit apparel and carpeting. Increased demand was reflected by some higher prices, although excess capacity, which is running at about 15% to 20%, and competition from imports tended to moderate price increases.

Production in the first half of 1977 increased by 11% over 1976 levels, while employment declined by 3% to 83,000. Wages remained well above the textile industry level, reaching an average hourly rate of \$5.75 by mid-1977. Most of the 79 man-made fiber establishments are located in the southeastern and middle Atlantic states, outside metropolitan areas.⁴

Noncellulosic Fibers

Noncellulosic fibers, which are synthesized from chemical compounds, continue to dominate the man-made fiber market and account for 80% of all production. Noncellulosic production totaled 6.6 billion pounds in 1976 and 3.7 billion pounds in the first half of 1977. Polyester, which is consumed chiefly in the apparel industry, accounts for over 50% of all noncellulosic production. Polyester production increased by 12% in the first half of 1977 over 1976 levels, with the largest increase reported in filament yarn for the improved doubleknit market. This increased demand was reflected by an increase of about one-third in prices of polyester filament over 1976 levels. Prices of polyester staples increased by over 8%.⁴

Nylon accounts for 30% of noncellulosic fiber production. Nylon production increased by 10% through mid-1977, benefiting chiefly from a strong market for carpeting, which is nylon's major consumer.

Production of acrylics and olefin, which account for nearly all of the remainder of noncellulosic production, increased by 17% and 7%, respectively. Other major markets for noncellulosics are tires and retail piece goods.

Man-Made Cellulosic Fibers

Man-made cellulosic fiber production totaled 848 million pounds in 1976 and about 465 million pounds in the first half of 1977, accounting for 11% of total man-made fiber production. Rayon constitutes two-thirds, and acetate, including diacetate and triacetate, the remaining one-third of cellulosic production. In the first half of 1977, rayon and acetate production increased by 15% and 2%, respectively, over 1976 levels. Rayon prices edged

up by 8% through late 1976 and early 1977 while acetate prices fell in late 1976 but largely recovered by mid-1977.⁴ Major markets for cellulosic fibers are medical, surgical and sanitary goods; drapery and upholstery; and dresses, blouses and apparel linings.

Textile Glass Fiber

Production of the 14 textile glass fiber plants operating in the United States totaled 714 million pounds in 1976. This was an increase of 28% over the previous year. Price increases resulted in a 38% increase in the value of shipments. In the first half of 1977, production was 5% above the 1976 level. Production capacity was expanded in 1977.⁴

The value of imports was \$4.7 million in 1976 and increased at more than double that rate in the first half of 1977. Exports totaled about \$21.5 million in 1976 and increased at a 15% annual rate in the first half of 1977. The major markets for textile glass fibers are reinforced plastics, draperies, upholstery, tires, and paper and tape reinforcement.

A.4 Imports and Exports

Exports exceeded imports in 1976, led by a 32% increase in export of noncellulosic fiber. Exports reached \$305 million and the trade surplus for man-made fibers reached \$228 million. In the first half of 1977, the value of cellulosic and noncellulosic fiber exports increased by 17% and 14%, respectively, over 1976 levels. Total man-made fiber imports were about 8% higher.⁴

Textile imports continued to increase in 1977 and totaled \$873 million in the first half of 1977, compared with \$834 million in the first half of 1976. Imports increased to \$1.41 billion in 1976, up 29% over 1975. The compound annual rate of growth between 1967 and 1976 was 6.5%.

Broadwoven fabrics continued to account for the largest share, by value, of total imports of textile mill products in 1977. Imports of broadwoven fabrics in the first half of 1977 were \$395 million, accounting for 53% of all textile imports. Cotton and man-made fiber broadwoven fabrics accounted for 39% and 28%, respectively, of all broadwoven fabrics imported. Imports of both carpets and knit fabrics increased in the first half of 1977 over the same period in 1976, with knit fabrics increasing by 86% during 1977.

In terms of square-yards-equivalent, cotton fabric imports declined by 40% during the first half of 1977 compared with a 66% annual increase in 1976. Wool and man-made fabric imports increased by 55% and 7%, respectively, in the first six months of 1977, compared with increases of 42% and 17%, respectively, in 1976. The major suppliers of textile imports are Japan, Hong Kong, the Republic of China, and the Republic of Korea.

Exports of textile mill products in 1976 were valued at \$1.45 billion, up 20% from \$1.21 billion in 1975. During the first half of 1977, exports of textile products at \$827 million were about 4% higher than for the same period

in 1976. Cotton broadwoven fabric exports in 1976 totaled \$499 million, accounting for 34% of textile exports. Total cotton broadwoven fabric exports declined by 7% during the first six months of 1977 to \$164 million, while wool fabrics were up 12% to \$2 million.

Exports of carpets in the first half of 1977 were \$52 million, slightly below the corresponding period in 1976, while knit fabrics declined 29% in the first half of 1977 to \$29 million. The major markets for U.S. textiles are Australia, Canada, Japan, and Western Europe.

A.5 Summary Data

The gross book value of depreciable assets and value of shipments for operating textile establishments in 1975 and 1976 are presented in Table A.5, and Table A.6 is a financial profile of the textile industry for 1976.

Table A.5 Gross Book Value of Depreciable Assets and Value of Shipments for Operating Textile Establishments, 1975 and 1976 (millions of dollars)

SIC Code	Industry Group	Gross Book Value of Depreciable Assets, End of Year ^a						Value of Shipments	
		Total		Structures and Buildings		Machinery and Equipment		1975	1976
		1975	1976	1975	1976	1975	1976	1975	1976
22	Textile Mill Products	13,684.7	14,215.0	3,547.9	3,601.0	10,136.7	10,613.9	31,063.6	36,389.2
2211	Weaving mills, cotton	1,597.2	1,623.5	394.3	391.1	1,184.9	1,232.4	2,956.5	3,717.9
2221	Weaving mills, man-made fiber	2,709.1	2,892.1	646.5	651.6	2,062.7	2,240.5	4,632.0	5,869.1
2231	Weaving, finishing mills	185.6	222.3(19) ^b	53.5	222.3(20)	132.1	158.8(18)	454.1	571.6(16)
2241	Narrow fabric mills	235.5 ^c	218.7	71.1	64.1	164.4	154.7	540.4	646.6
225	Knitting mills	2,784.4	2,756.1	682.2	695.7	2,102.1	2,060.3	8,294.9	8,625.7
2251	Women's hosiery except socks	331.4	308.2	98.6	93.9	232.9	214.2	762.5	713.5
2252	Hosiery, nec	196.2	201.2	47.3	50.1	148.8	151.1	720.6	798.3
2253	Knit outerwear mills	444.2	451.7	129.3	136.4	315.0	315.3	1,995.7	2,140.7
2254	Knit underwear mills	140.7	150.6	55.4	57.8	85.2	92.7	637.9	663.9
2257	Circular knit fabric mills	1,219.4	1,145.9	226.9	221.5	992.6	924.4	2,791.1	2,816.5
2258	Warp knit fabric mills	410.5	464.4	111.6	124.8	299.0	339.7	1,264.8	1,384.8
2259	Knitting mills, nec	d	34.2(27)	d	11.2(32)	d	23.0	122.3	108.0(15)
226	Textile finishing, except wool	1,263.8	1,322.2	360.6	367.7	903.1	954.6	3,033.4	3,542.2
2261	Finishing plants, cotton	334.8	344.1	93.0	93.5	241.8	250.6	631.1	737.3
2262	Finishing plants, man-made fiber	712.0	768.0	211.2	221.1	500.8	545.8	1,878.3	2,158.0
2269	Finishing plants, nec	216.9 ^c	210.1	56.4	52.0	160.6	158.1	523.9	646.8
227	Floor covering mills	903.8	885.5	297.9	286.5	605.9	599.0	3,240.0	3,794.9
2271	Woven carpets and rugs	97.4 ^c	94.9	31.8	32.1	65.6	62.8	179.9	204.0
2272	Tufted carpets and rugs	773.8	757.7	254.6	243.0	519.1	514.7	2,960.7	3,486.1
2279	Carpets and rugs, nec	32.6 ^c	32.9	11.5	11.5	21.1	21.4	99.4	104.8
228	Yarn and thread mills	2,671.3	2,843.8	640.2	661.3	2,031.0	2,182.4	4,694.9	5,844.0
2281	Yarn mills, except wool	1,533.7	1,554.9	369.7	367.2	1,164.1	1,187.7	2,541.4	3,398.5
2282	Throwing and winding mills	939.5	1,087.4	214.5	240.1	725.0	847.3	1,593.1	1,773.2
2283	Wool yarn mills	44.9 ^c	47.3(34)	14.6	13.2(33)	30.3	34.0(36)	162.7	216.0
2284	Thread mills	153.1	154.2	41.4	40.8	111.7	113.4	397.7	456.3

Table A.5 (Cont'd)

SIC Code	Industry Group	Gross Book Value of Depreciable Assets, End of Year ^a							
		Total		Structures and Buildings		Machinery and Equipment		Value of Shipments	
		1975	1976	1975	1976	1975	1976	1975	1976
229	Misc. textile goods	1,352.1	1,450.7	401.5	419.6	950.5	1,031.1	3,217.4	3,777.2
2291	Felt goods, except woven and hats	78.1 ^c	78.4	21.1	22.0	57.0	56.4	145.4	158.0
2292	Lace goods	18.8 ^c	21.1(18)	6.5	6.5(18)	12.4	14.7(20)	27.9	33.8(36)
2293	Paddings and upholstery filling	59.4	66.6	22.1	23.3	37.3	43.2	156.1	210.0
2294	Processed textile waste	35.8	40.7	14.8	13.6	22.1	25.9	146.9	166.3(17)
2295	Coated fabrics, not rubberized	401.7	428.0	121.3	126.3	280.3	301.8	986.1	1,182.5
2296	Tire cord and fabric	277.0	277.7	71.1	70.9	205.9	206.8	748.9	835.7
2297	Nonwoven fabrics	261.6	298.1	69.9	77.8	191.7	220.3	565.3	670.4
2298	Cordage and twine	107.1 ^c	114.0	34.6	37.1	72.5	76.8	288.3	300.1
2299	Textile goods, nec	112.6 ^c	126.2(30)	41.3	41.0(53)	71.3	85.2(20)	162.6	220.3(27)

^aThe data encompasses all fixed depreciable assets on the books of establishments at the end of the year. The values shown (book value) represent the actual cost of assets at the time they were acquired, including all costs incurred in making the assets usable (such as transportation and installation).

^bSampling errors (the differences between the estimates obtained and the results theoretically obtainable from a comparable complete coverage survey) are unknown. However, guides to the potential size of the sampling errors are provided by estimates of errors. Any figure with an associated error exceeding 15% (given in parentheses) may be of limited reliability.

^cRevised.

^dWithheld because estimates did not meet publication standards (data were unreasonable or inconsistent).

Source: Ref. 6.

Table A.6 Profile of Textile Industry (SIC 22), 1976

Total employment	875,900
Salary and wages	\$7,368.3 million
Production workers	765,300
Man-hours	1,518.3 million
Workers' wages	\$5,769.3 million
Value added	\$14,494.9 million
Supplemental labor cost	\$987.9 million
Cost of materials	\$22,994.2 million
Value of shipments	\$36,388.9 million
New expenditures	\$1,087.5 million
Inventories	\$5,015.0 million
Total assets	\$14,215.1 million
Total rents	\$206.1 million
Age of structures and equipment	More than 74% in excess of 10 years
Ratio of:	
(Salary & wages)/value shipments	0.202
Cost of material/value shipments	0.610
Workers' wages/value shipments	1.159
(Supplemental labor + salary & wages)/value shipments	0.230
(Cost material + supplemental labor + salary & wages)/value shipments	0.840
Total rents/value shipments	0.006
Total assets/value shipments	0.391
Value added/value shipments	0.398
Inventories/value shipments per month	1.654
Salary & wages/value added	0.508
(Supplemental labor + salary & wages)/value added	0.576
Value added/man-hrs	9.547
Man-hrs/production workers	1.984
(Salary & wages)/total employment	8.412
Supplemental labor/total employment	1.128
Total assets/total employment	16.229
Value added/total employment	16.549
Current to previous ratios:	
Total employment	4.9
Value of shipments	17.1
Inventories	8.2

Source: Ref. 62

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APPENDIX B

DESCRIPTION OF TEXTILE MANUFACTURING PROCESSES

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Opening, Blending, and Picking

The first operation in a textile plant takes place in the opening room, where bales of cotton or man-made fiber staple are opened. Portions of the fiber staple are placed in opening machines, where the fiber is fluffed and some foreign matter is removed. Two or more fibers can be blended either at this point or during subsequent processes. The fiber emerges from the opening machine as bits of fluff, which are then carried by air to a cleaning machine, called a picker. Here the fiber is beaten and further cleaned, and a loose, uniform sheet of fiber (called picker lap) is formed.

Carding

The sheets of fiber so formed are sent on to card machines. A card machine contains many long, rectangular, slowly moving slats covered with fine teeth. The fiber sheet passes between the slats and the cylinder and is further cleaned, then removed from the cylinder and condensed into a web. This is passed through rollers and formed into rope-like strands called slivers (pronounced "sly-vers") which are automatically coiled into tall, cylindrical cans.

Drawing

The cans of sliver are moved to a position near a drawing frame, where as many as 60 slivers are fed into the drawing frame, which lays out, or draws out, the fibers and makes them parallel.

Lapping

From the drawing machine, the drawn slivers are fed into a ribbon lap machine and are formed into a ribbon lap, or sheet, which is wound into a roll.

Combing

During combing, eight rolls of ribbon lap are fed into a comber, which, with a series of fine steel teeth, combs out the short fibers, leaving only the longest and strongest. These fibers are formed into one strand of sliver. This goes to a finishing drawing frame, where fibers are again laid out, or drawn out, parallel to each other and formed into yet another sliver.

The combing process may be bypassed, in which case the slivers produced by carding and drawing are moved directly to the roving frame.

Roving

On the roving frame, individual slivers are passed between a series of three rollers, and are compressed and greatly reduced in diameter. During this process the fibers are given a slight twist, which imparts the first man-made strength, and the resulting roving slivers are wound on bobbins.

Spinning

On the spinning frame, roving sliver is again drawn through a series of rollers of varying speeds. These stretch the sliver still further, and the roving sliver is twisted 10 to 30 turns per inch to form firm, strong yarn which is wound on bobbins. The amount of twist produced by the spindles determines the character of the yarn and its end use.

Spooling

Bobbins of yarn go first to a spooler, where the yarn is wound onto "cheeses" (a type of yarn package). In many plants, bobbins of yarn go directly from the spinning frame to the loom to be put in shuttles for "filling" (the crosswise threads in cloth).

Warping

The "cheeses" of yarn from the spooler are moved to a warper or are shipped directly to knitting plants. The warping machine winds hundreds of separate strands of yarn onto a large spool called a beam. Warp yarn is for the lengthwise threads in cloth.

Slashing

The beams of warp yarn go to a slashing machine, where the yarn from several beams is combined and treated with a hot solution of starch, wax, oils, and water to coat and strengthen the yarn to reduce breakage and damage in the weaving process. Treated yarn passes over hot pressurized cans for drying and curing, then the machine winds the yarn onto a beam -- a huge roll.

Weaving

Several types of looms are used to weave fabric. These include the shuttle and shuttleless looms; the Jacquard loom, on which the most intricate patterns are woven; and the box loom, on which plaids and multicolor cloths are woven. The unfinished woven cloth produced is termed "grey" goods, or griege. Carpets and bedspreads are made on special machines called tufting machines, and knitted goods are made on knitting machines. The woven cloth is inspected and then sent on to be finished.

Finishing

Figure B.1 is a sketch of a typical process range in a finishing plant (finishing refers to bleaching, dyeing, printing, and other processes, plus all drying between operations and final drying and heat setting). Energy requirements of natural-gas-fired equipment are given. The dye range represented is a thermal dye range; however, atmospheric dye becks (see below) are commonly used. The glossary in Table B.1 explains the functions of the various pieces of equipment.

Desizing

The first step in the finishing process is desizing. Grey cloth is sewn into a continuous piece from 1,000 to 100,000 yards long. After an enzyme bath, the cloth is deposited in deep bins for chemical activity, then is washed thoroughly for the removal of chemical.

Bleaching

After desizing and scouring, the grey cloth is bleached. Mercerization is an optional process in which the cloth is sprayed with a caustic solution to return it to a uniform width; if used, the process usually occurs between the scouring and bleaching operations, although in Fig. B.1 it is shown following desizing.

Dyeing

There are several methods of dyeing. In package dyeing, large numbers of "packages" of yarn are put on a carrier frame. In another commonly used method, bleached goods are continuously fed into large vats, or dye becks, in water containing chemicals and dye, which is then heated to a high temperature. The beck may be operated at atmospheric pressure (and would be referred to as an atmospheric dye beck) or at elevated temperature and pressure. Finally, goods can be continuously dyed in open widths by pad-fix operation. The dye is padded on, the excess squeezed out, the fabric predried, and the dye fixed by thermal treatment (hot air, steam, etc.).

Printing and Finishing

Dyed cloth may be imprinted with a design or used as a solid color. In either case, the unfinished cloth will be sent on for finishing to impart certain characteristics.

Drying and Heat Setting

Fabric is dried between operations and is the final step in the production of finished fabric goods. It may also be dried at high temperatures, with or without chemicals added to it, to impart certain desirable, permanent characteristics. This process is called heat setting.

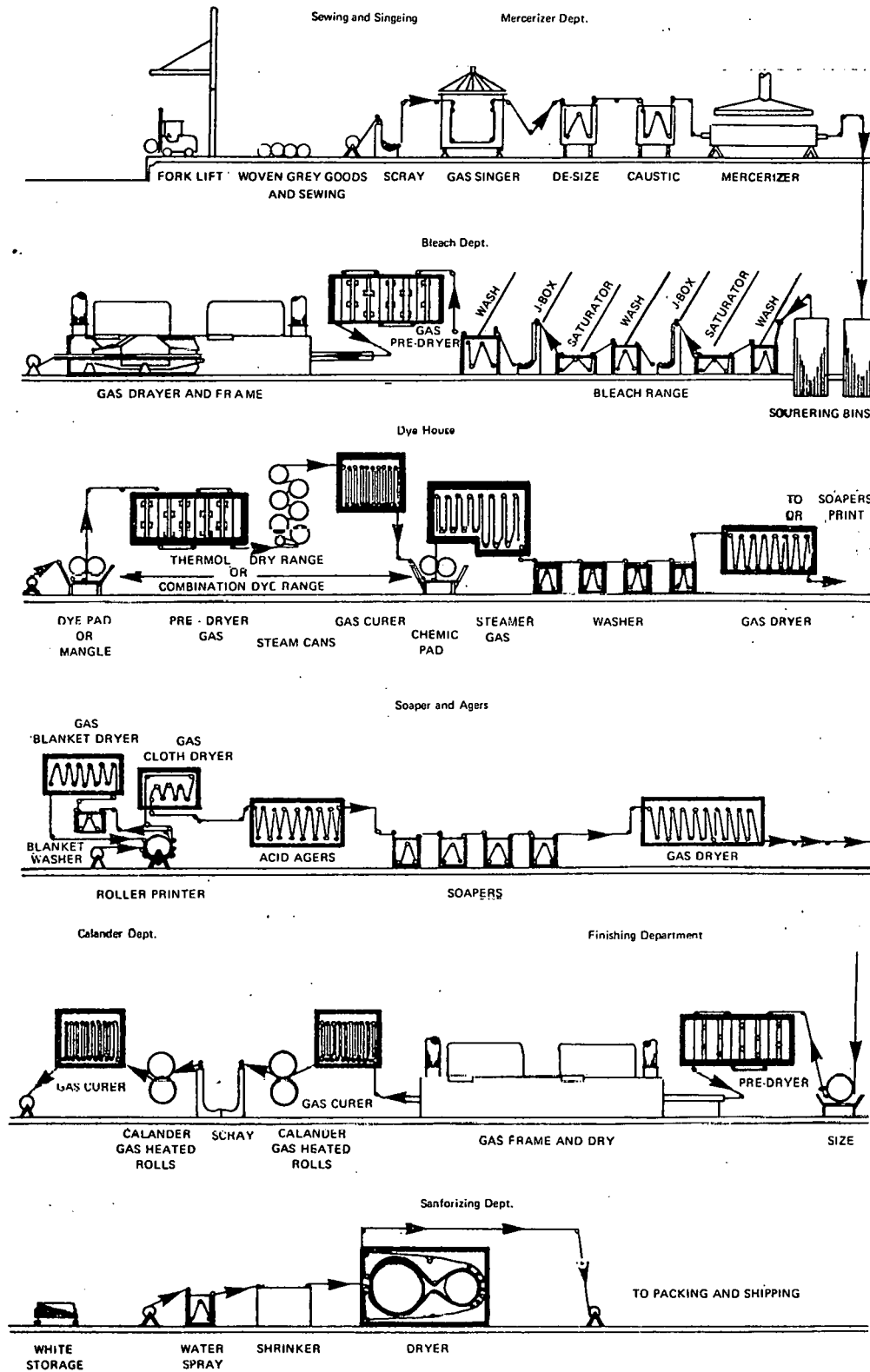


Fig. B.1 Sketch of Typical Process Range in a Textile Finishing Plant (Source: Ref. 14)

Table B.1 Glossary for Sketch of Process Range (Fig. B.1)

- Gas Singer: To remove fuzz and give a finer appearance. Also to prepare the surface of the woven material to permit even dyeing, printing, and other finishing operations.
- Desize: A liquid chemical compound used to remove the starch, wax, and oil solutions used in the slashing operation.
- Caustic: A caustic soda solution used to expand the fibers for more uniform absorption.
- Mercerizer: Spraying a caustic solution on the cloth to bring the width back to uniformity.
- Souring Bins: A detention time during the process for chemical reactions to take place.
- Washer: Detergent and water wash cycle to remove excess chemical and residue.
- Saturator: To apply the type of bleach required for the particular fabric in process.
- J-Box: An accumulator for detention to allow time for bleach reaction.
- Gas Pre-Dryer: To bring the fabric up to a predetermined temperature and reduce the moisture content in proportion to the operation. Gas requirements are 1,000 to 5,000 ft³/h.
- Gas Dryer Frame: To stretch and dry the cloth uniformly to the point of normal regain. Gas requirements are 4,000 to 7,000 ft³/h.
- Dye Pad or Mangle: To pad on the dye stuff uniformly both in the soluble or insoluble state.
- Pre-Dryer: To bring the cloth up to temperature and reduce the moisture content approximately 30% before entering the dry cans. This is to prevent an inrush or migration of the dye stuff. Gas requirements are 2,000 to 4,000 ft³/h.
- Gas Curer Box: Used for thermic reaction dyes such as DuPont Thermosol and others. Gas requirements are 3,000 to 5,000 ft³/h.
- Chemic Pad: To pad on hydro and caustic chemicals.
- Gas Steam: Used for reduction of dye stuff. (Changing insoluble dye stuff into soluble.) This reduces and fixes the colors.
- Washer: To remove the excess dye stuff and chemic from the fabric.
- Gas Dryer or Curer: To dry and/or cure the fabric in preparation for further processing. Gas requirements are 5,000 to 7,000 ft³/h.
- Roller Printer: A series of engraved rolls to apply colors for various patterns and prints. The cloth passes between the print rolls and an endless blanket. As the blanket travels through its cycle, it is washed and dried in one continuous operation. Gas requirement of the blanket dryer is 4,000 to 6,000 ft³/h.
- Acid Ager: Acetic acid is used to develop certain types of dyes and colors.
- Soapers: To wash the cloth and remove excess acid and residue.

Table B.1 (Cont'd)

Gas Dryer: To dry the cloth after the final wash. Gas requirements are 4,000 to 7,000 ft³/h.

Size: Starch mangle or pad to apply the type of size or resin needed.

Pre-Dryer: To bring the cloth up to drying temperature and remove approximately 30% of the moisture. Also to start the curing process of the size or resin.

Frame and Dryer: To stretch and control the width of the cloth uniformly during the drying operation. Gas requirements are 5,000 to 7,000 ft³/h.

Gas Curer: To cure the resins required in various finishes.

Calender Rolls: Used for ironing and pressing. Gas requirements are 125 to 150 ft³/h.

Gas Curer: The final cure for quality control of the various finishes.

Sanforizing: The shrinkage is controlled in this department then sanforized to prevent further shrinkage.

APPENDIX C

SELECTED MAJOR JOURNALS; TRADE PUBLICATIONS, AND
TRADE ORGANIZATIONS OF THE TEXTILE INDUSTRY

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Journals (Refereed)

American Dyestuff Reporter
SAF International, Inc.
630 Third Avenue
New York, N.Y. 10010

Monthly: \$10

International Dyer, Textile Printer, Bleacher and Finisher
Textile Business Press, Ltd.
Statham House, Talbot Rd.
Stretford, Manchester M32 0FP, Eng.

Semimonthly: 9 pounds sterling

Society of Dyers and Colourists Journal
Society of Dyers and Colourists
Box 244, Pekin House
Grattan Road
Bradford, Yorkshire, BD1 2JB, Eng.

Monthly w. membership;
nonmembers: 14 pounds sterling

Textile Chemist and Colorist
American Association of Textile Chemists and Colorists
Box 12215
Research Triangle Park, N.C. 27709

Monthly: \$7.50 to nonmembers,
incl. ann. Buyers Guide

Textile Research Journal
Textile Research Institute
Box 625
Princeton, N.J. 08540

Monthly: \$75

Advertising, book reviews, abstracts, bibliographies, charts (diagrams, graphs, tables), illustrations, patents, trade literature (manufacturers' catalogs, etc.), index. Circ: 12,000. Indexed in: Applied Science & Technology Index, Biological Abstracts, Chemical Abstracts, Engineering Index.

Advertising, book reviews, abstracts, illustrations, patents, trade literature. Indexed in: British Technology Index, Chemical Abstracts.

Advertising, book reviews, abstracts, bibliographies, charts, illustrations, patents, statistics, index, cumulative index. Circ: 5,000. Indexed in: Applied Science & Technology Index, British Technology Index, Chemical Abstracts.

Advertising, book reviews, bibliographies, charts, illustrations, index, cumulative index. Circ: 13,700. Also available in microform from UMI (University Microfilms International, 300 N. Zeeb Rd., Ann Arbor, Mich. 48106; UMI Ltd., 18 Bedford Row, WC1R 4EJ, London, Eng.).

Advertising, book reviews, bibliographies, charts, illustrations, index. Circ: 2,500. Also available in microform from UMI (see above for address). Indexed in: Applied Science and Technology Index, Applied Mechanics Review, Biological Abstracts, Chemical Abstracts, Engineering Index, RAPRA (Rubber and Plastics Research Association of Great Britain), Science Abstracts.

Trade Publications (Nonrefereed)*Textile Industries*

W.R.C. Smith Publishing Co.
1760 Peachtree Rd., N.W.
Atlanta, Ga. 30357

Monthly: controlled free circ.;
\$5 to others

Advertising, book reviews, charts, illustrations, trade literature, index. Circ: 32,150. Also available in microfilm. Indexed in: Applied Science and Technology Index, Chemical Abstracts, Engineering Index.

Textile World

McGraw-Hill, Inc.
1175 Peachtree St.
Atlanta, Ga. 30361

Monthly: \$15

Advertising, book reviews, charts, illustrations, trade literature. Circ: 31,875 (6 mos.). Also available in microfilm from UMI (see *Textile Chemist and Colorist* for address). Indexed in: Applied Science and Technology Index, Business Periodicals Index, Chemical Abstracts, Engineering Index, RAPRA.

Trade Organizations

American Textile Manufacturers Institute (ATMI)

400 S. Tryon St.
Suite 2124
Charlotte, N.C. 28285
(704) 334-4734

1101 Connecticut Ave., N.W.
Suite 300
Washington, D.C. 20036
(202) 862-0542

Staff of 50. Textile firm operating machinery for manufacturing and processing cotton, man-made wool and silk textile products; includes spinning, weaving, bleaching, finishing, knitting, and allied plants; does not include firms that produce man-made fibers and yarn by a chemical process and manufacturers of hosiery. Operates public relations program for the industry, government relations program, textile market program, and statistical information service. Holds seminars and periodic meetings. Maintains library of 1200 volumes. Also has office in New York City.

Committees: Carpet, Communications, Consumer Affairs, Cotton, Economic Policy, Education, Employee Benefits, Environmental Preservation, Finishers, Information Services, International Trade, Knit Fabrics, Law, Metric Conversion, Research and Technical Services, Safety and Health, Tax, Textile Market, Traffic, Wool.

Divisions: Communications, Economic Information, Market.

Publications: Textile Trends (weekly), Public Relations Pointers (monthly), Textile Hi-Lights (quarterly), Official Directory (annual). Also publishes bulletins.

Convention/Meeting: 1980 - March 26-28, Kauai, Hawaii; 1981 - April 2-4, San Francisco.

Carpet and Rug Institute (CRI)
P.O. Box 2048
Dalton, Ga. 30720
(404) 278-3176

Members, 300. Staff, 14. Manufacturers of carpets, bath mats, bedspreads, and suppliers of raw materials and services to the industry. Compiles statistics on shipments, dollar value, materials used, etc.

Committees: Budget, Finance, and Pension Administration; Environmental; Financial Executives; Government Affairs; Industrial Relations; Installation; Marketing; Steering; Rug Manufacturers; Technical; Traffic.

Publications: Reports (biweekly), CRI News (bimonthly), Carpet Specifiers Handbook (annual), Directory and Report (annual). Also publishes books dealing with carpet maintenance, and various aspects of the carpet industry.