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ENERGY REQUIREMENTS OF THE U.S. PULP AND PAPER INDUSTRY

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5.0 Scope and Recommendations

The following study of the energy requirements of the U. S. pulp and paper industry tries to establish order-of-magnitude data. In view of the great divergency of products, processes, plant designs that reflect on specific energy consumption rates, it is not possible to provide greater detail.

Some of these considerations have been recognized by the industry, which is now attempting to improve the data base, using a systems analysis approach, thoroughly to investigate the energy implications of the different processes and products.

No attempt has been made to recommend specific process modifications, and the study restricts itself to pointing out how public policy can help to channel the industry's efforts into less energy-intensive practices.

Most of these considerations have been developed in Section 5.2.1, Energy and the Paper Industry, which also offers the following recommendations:

* Government should support improved materials effectiveness in the pulp and paper industry which will also result in substantial fuel economies, especially by promoting recycling and "whole tree harvesting"

* Disallowance of special tax treatment for capital gains on standing timber will eliminate, in future, preference for virgin raw material, and will stimulate the use of recycled paper

* Support should be given to industry to make full use of all values contained in timber, including the harvesting of the entire tree, thereby maximizing power generation by pulp mills from wood values now frequently wasted

* Support should be given to municipalities to promote source separation of paper to improve recycling and alternatively use of paper as supplemental fuel in power generation (it is of great importance that this matter be fully and promptly investigated and discussed before a commitment is made by municipalities to burn the entire municipal solid waste without requiring source separation of potentially recyclable paper, such as newsprint, magazines and stationery)

* Studies might be needed to determine why the U. S. had considerably better recycling rates in former decades and what action foreign governments have taken to improve the reuse of waste paper

* Further study is suggested to develop the concept of using low-grade steam, e.g., from power plants or geothermal sources, to supply the needs of paper mills for process heat requirements. This approach might well need government stimulation to effect energy savings, in view of institutional inhibitions

* Encouragement now provided through industry efforts to expand its "in house" energy base through increased power and steam generation from waste products, through greater energy economy, through conversion from critical to more expendable fuels, through research into energy-saving process modification--should be further expanded

* Technology transfer from bench scale research and pilot plant operations to commercialization should be facilitated by government underwriting some of the financial risks, either by direct funding or special tax incentives.

5.1 Introduction

A reedy plant, Papyrus, from which the Egyptians produced a writing material, gave its name to paper, which was then produced as a sheet for writing by layering the reed, wetting, compacting and drying it.

In essence the nature of paper has not changed. It is still defined as a matted or felted sheet, produced from a suspension of fibers in a fluid medium by retention on a sieve or wire mesh, followed by drying and finishing.

Modern papermaking seems to have originated in China, where vegetable fibers were combined with textile waste. This invention travelled slowly westward and reached Europe in the fourteenth century (just in time for the invention of the printing press).

Rags were the principal raw material for paper through the eighteenth century. Then, work in France, Britain and Germany brought about the development of mass production of paper based on wood pulp.

Since the middle of the nineteenth century, paper and paper board have been made by felting wood fibers, i.e. cellulose. Cellulose is obtained from wood which consists of about one half water, the other half being three-quarters cellulose, which is bonded by lignin (about one-quarter). Wood also contains some 2% of "extractives," pitch, oils, turpentine.

Wood pulp is made by removing the bark from trees (debarking) and then generating the fibers either by mechanical or chemical means or a combination of the two. Chemical pulping can be acid (sulfite) or alkaline (soda or sulfate). Mechanical pulping yields much more fiber (95%), compared to chemical (45%), but is of lower quality.

Wood pulp must be processed by washing, screening, thickening, and, frequently, bleaching. In paper manufacture, the pulp is suspended in water, perhaps beaten and further treated by such means as loading with chemicals, and then felted into a paper through removal of the water by filtering, pressing, drying and rolling, and possibly finishing the paper to confer desired properties.

There is a wide range of properties in papers, depending on the tree species, pulping method, chemical treatments by bleaching or additions. Process adjustments are needed to supply the vast variety of paper products, but they also result in a great variety of paper-making plants. Fig. 5.1A provides an overview of the steps involved in paper making.

In the U.S., production of one ton of paper and board required in 1977 .77 tons of pulpwood, .1 tons of other fibers, and .21 tons of recycled waste paper. The pulpwood represented an average input of about 2.2 tons of debarked wood, which in turn came from 2.5 tons of timber. Thus to supply the 60 million tons of paper and paperboard currently consumed in the U.S., 150-160 million tons of timber must be cut, or more than half the U.S. timber production.

As a result of the wide range of possibilities with respect to the age of pulp and paper plants, their size and design, the raw material mix used for the paper, the integration between pulp and paper production, and the ultimate product, it is not possible to provide generalized energy consumption data for specific products, industry-wide. The U.S. Bureau of the Census and the American Paper Institute (API) offer figures and energy consumption for the U.S. pulp and paper industry (which are in fair agreement).

To produce one ton of paper and board, 43 million BTU are consumed, of which 18 million were generated from recycled or internally generated energy, resulting in a net energy consumption of 25 million BTU or about

1 ton of coal equivalent. In the aggregate this net energy need amounts to 1.5 billion million BTU or about 60 million tons of coal equivalent, equal to 10% of total domestic coal production.

The value of industry shipments is in the $ 10 billion range for paper and paperboard.

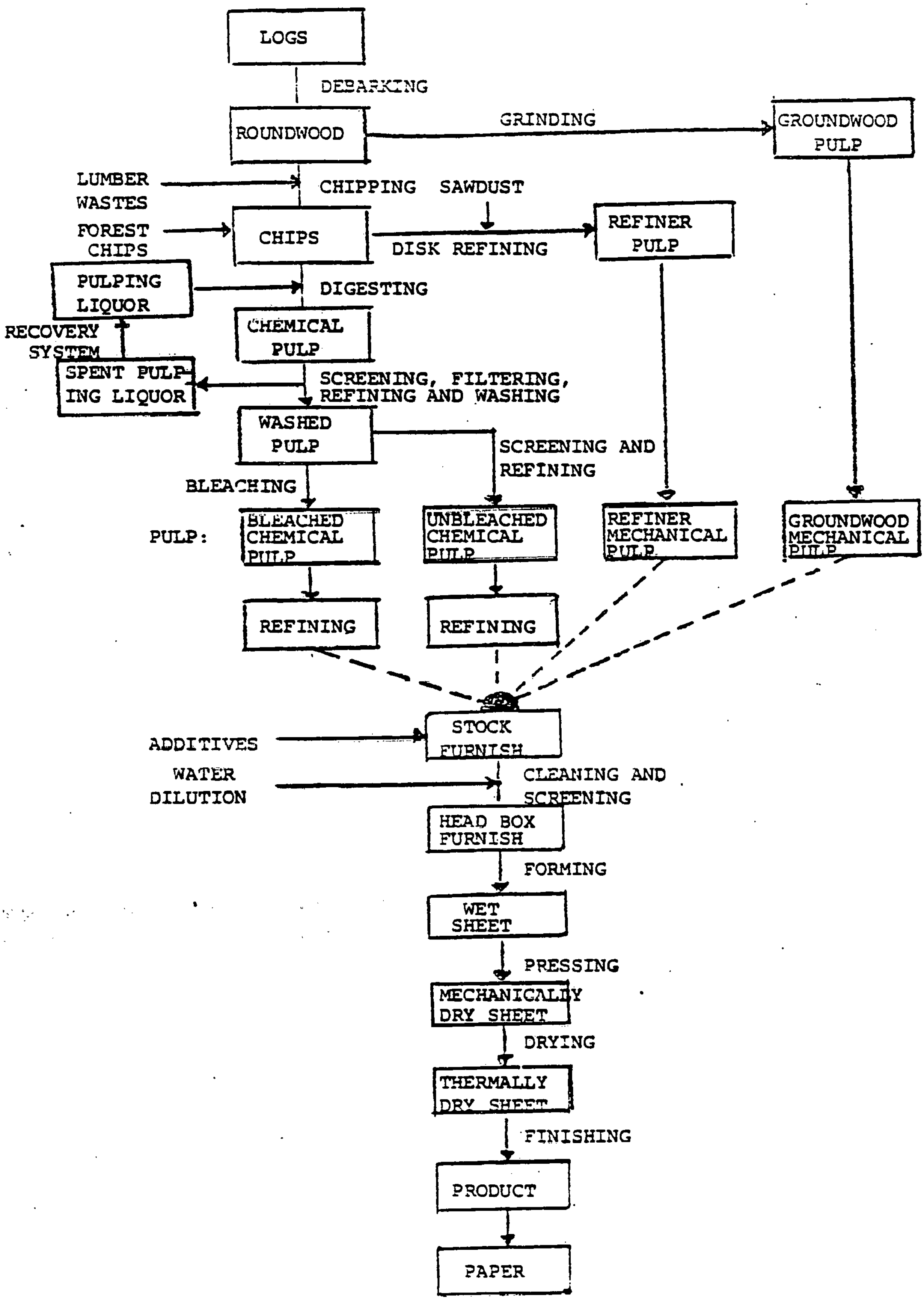


FIG. 5.1A: OUTLINE OF THE PAPERMAKING PROCESS

5.1.1 Properties of Paper

The basic parameter for the description of paper is its weight per unit area as follows:

Paper Grade	Weight, lb./ream*
Blotting paper	114 - 266
Bristol, postcard	135
Cover Stock, file folders	66 - 216
Book, coated two sides	45 - 109
Multiwall bag stock	40 - 70
Newsprint	30 - 35
Book, uncoated	27 - 91
Bond	25 - 60
Greaseproof, glassine	20 - 50
Envelopes	16 - 40
Manifold tissue (a)	10 - 20
Facial tissue	9 - 10
Tea-bag tissue	8 - 12
Carbonizing tissue (b)	5 3/4 - 25
Kraft wrapping	25 - 80

*weighed at 75°F, 50% relative humidity
480 sheets cut to 24 x 36 in.

(a) for making several carbon copies
(b) for making carbon paper

The above table provides only a small sample of the range of papers that are articles of commerce. Thickness and density can vary widely (e.g. from a specific gravity of .1 to 1.4). Strength depends on the strength of the individual fiber (which can vary with the type of fiber and with the treatment it has undergone), its length, the bond between the fibers, and the structure and formation of the sheet, the addition agent used, and the aftertreatment given by physical means or chemical agents.

The strength of the paper is expressed by defining the breaking length, i.e. the length of a strip that can just support itself without rupturing. Another definition of strength is the bursting strength, which is important for other applications (e.g. for paperboard), and it gives the force needed to rupture a defined circle.

Wet strength, combined with maximum absorbency for water, is needed in sanitary or filter papers or paper towels. Ordinary paper suffers considerable degradation when wet, while treated papers can retain almost half their strength. Resistance to liquid penetration, e.g. of oil or grease, can also be prevented by modification of the surface with rosin or size.

Stiffness is demanded in some papers, softness in others. These properties can be modified depending on compactness, bonding, and surface treatment.

Much depends on the degree to which the pulp is beaten before processing. The hydrophyllic nature of cellulose can best be retained by lightly beating the raw material: this produces an absorbent material. A low-porosity stock can be obtained by extensive beating (leading in the extreme to a grease-proof paper).

Optical properties are defined by color, brightness, opacity, and gloss, and there are definitions and measurements for each.

5.1.2 Uses of Paper

Table 5.1.2A: Apparent Consumption of Paper and Paperboard in the U.S., 1960 to 1977, in Millions of short tons

	1960	1965	1970	1975	1976	1977**
Total, paper & board	39.2	49.2	58.1	55.5	64.6	60.8
Paper	20.6	25.2	30.1	28.4	32.7	27.3
Newsprint	7.3	8.4	9.8	9.2	9.9	5.2
Coated print'g, etc.	2.1	2.8	3.2	3.2	3.9	4.3
Bookpaper, uncoated	1.6	2.1	2.7	2.5	2.9	3.0
Other print'g, writ'g	3.2	4.3	5.3	5.3	6.4	5.0
Packag'g & industrial	4.2	4.8	5.3	4.5	5.5	5.7
Tissue & creped	2.2	2.9	3.8	3.8*	4.0*	4.1
Paperboard	15.2	19.7	23.4	22.3	26.5	27.9
Unbleached kraft	4.8	6.9	9.9	10.4	12.1	13.4
Bleached fiber	1.7	2.2	3.3	3.1	3.3	3.7
Semichemical	1.7	2.6	3.4	3.5	3.7	3.8
Combination furnish	7.0	8.0	6.9	5.5	6.4	7.0
Wet machine board	.2	.2	.1	.1	.1	.1
Const. paper & board	.3	4.1	4.4	4.7	5.3	5.5

Source: Statistical Abstract of the United States, 1974, updated.

* Recycled Furnish

**From Table 5.2.2A, preliminary

Table 5.1.2A sets forth the major uses of paper and shows the statistical record for the past few years. (More detailed information is provided below.)

The principal uses for paper and paperboard are as follows:

(1) Newsprint (or groundwood) paper is made from ground pulp with a small amount of chemical wood pulp (for better strength and durability). This grade is also used for some magazines, paperback books, catalogs and general commercial printing. It tends to yellow in light or under aging.

(2) Coated or uncoated book papers are made from combinations of chemical wood pulp, but lower grade papers are also used. These papers can be lightly or heavily finished (e.g. by calendering, i.e. rolling), they can be pigmented (by "loading" with titanium dioxide or other compounds), or they may contain special long fibers and/or bonding agents.

(3) Bond paper has great stiffness and durability; it is bright and clean. There are two grades based either on rag content or chemicals-containing pulps. They are used for important applications such as currency, legal documents, quality stationery, tracing paper, and cigarette paper.

(4) Bristol is used for postcards or such products as computer punch cards. It is made from combinations of chemical pulp which is beaten and well sized.

(5) Sanitary papers are used in towelling, tissue, napkins, etc.; they are made from sulfite or bleached kraft pulps with little treatment to preserve absorbency. The paper can be "creped." Wet strength is important for this application.

(6) Paperboard is over .012 in. thick and made from wood pulp, waste paper, straw, singly or severally: (a) box board is used in food boards, trays, plates, paper boxes; (b) container board goes into corrugated or solid fiber shipping containers; and (c) specialties are, among others:

building, electrical and automotive boards.

This outline barely skims the surface of the subject of paper products. There are literally hundreds of uses and grades for most of them. Differences can be the result of the use of different raw materials, tree species, use of recycle, admixture of chemicals or textile fibers, as well as variations in processing.

Domestic production supplies about 90% of apparent U.S. paper consumption; the balance is made up by imports from Canada. Actual production, exports, imports are shown in Table 5.1.2B, below.

Table 5.1.2B: U.S. Paper and Board Production, Imports, Exports and Consumption, 1899-1977, in Millions of Tons

Year	Production	Imports	Exports	Apparent Consumption	lb./capita
1899	2.2	---	---	2.2	58
1909	4.1	---	---	4.1	91
1919	6.0	.7	.4	6.2	120
1929	11.5	2.5	.3	13.4	220
1939	13.5	2.7	.2	15.9	244
1950	24.4	5.0	.4	29.0	381
1955	30.2	5.4	.8	34.7	419
1960	34.4	5.7	1.0	39.1	433
1965	44.1	6.8	1.8	49.1	506
1970	53.5	7.3	2.8	57.9	566
1974	61.0	7.2	3.8	64.4	607
1975	52.9	6.2	3.0	56.1	524
1976	60.5	7.0	3.4	64.1	596
1977	61.9	7.5	3.2	66.2	613

Source: Slatin, B., Economic Structure of the Paper Industry, TAPPI, 58:7, July 1975--updated by Census data.

Paper production and consumption in the U.S. grew according to the above record at a compound rate of about 4.8% over a period of 80 years. This does not appear to be very impressive until it is realized that during this time the U.S. population grew approximately threefold and yet per capita consumption of paper expanded by an order of magnitude from about

60 to over 600 lb. per capita.

If paper production continues at the past growth rate, then consumption will be in the order of about 220 million tons by the year 2000, or around one ton per capita. This prospect appears both formidable and unlikely.

The geographical distribution of important papermaking activities is presented in the following table.

Table 5.1.2C: States Leading in the Production of Wood Pulp, Paper and Board, and in the Number of Mills; Consumption of Raw Materials by the Paper Industry.

Leading Wood Pulp Producing States, 1974, Million tons

Georgia	5.4
Alabama	4.0
Washington	3.6
Louisiana	3.5
Florida	3.3
Oregon	2.9
Maine	2.4
Mississippi	2.3
South Carolina	2.3
Virginia	2.0
	31.7 = 65% of U.S. output

Leading Paper and Board Producing States, 1974, Million tons

Georgia	4.6
Alabama	3.8
Louisiana	3.7
Wisconsin	3.6
Oregon	3.1
Maine	2.8
Washington	2.6
Florida	2.5
Michigan	2.5
Pennsylvania	2.5
	31.6 = 53% of U.S. output

Leading States with Number of Paper & Board Mills, 1974

	Number	Production, Million tons
New York	69	2.1
Pennsylvania	54	2.5
Massachusetts	52	.8
Wisconsin	51	3.6
Ohio	43	2.1
California	41	1.9
Michigan	39	2.5
New Jersey	35	1.2
Oregon	27	3.1
Illinois	24	1.0
	435	20.8
Of U.S. Total	56%	35%

Raw Materials Consumption by Pulp & Paper Mills was in 1975 65.7 million cords pulpwood, 42.6 million tons wood pulp, 11.7 million tons waste paper, 712,000 tons cotton linter, rags, straw, hemp, etc.

Source: Lockwood's Directory, 1977.

The foregoing table shows that there is a concentrated region of wood pulp production in the southern states, where the rapid growth of timber provides a good raw material, as well as in the Pacific Northwest and Maine, where large timber operations offer opportunities for wood pulp manufacture. Substantial paper and paperboard plants have located close to the raw material source, according to the second portion of the table, in the South and Washington, Oregon and Maine, but also in Michigan and Pennsylvania.

The large number of paper and board mills indicates that there are possibly many smaller plants operating, because they were established close to market on a raw material base that may have dwindled over the years.

It will be seen that the ten leading states produce two-thirds of the country's wood pulp and one-half of the paper and board. Georgia and Alabama are the leading states, responsible for 19% of the wood pulp and 14% of the paper and board in 1974. By contrast, the three states with the largest number of paper and board mills, which totalled 23% of the total producing units, contributed only 9% to the output of paper and board of the country.

The most important growth in timber and pulp production has occurred in the South (where land has been converted from cotton to timber--southern pine, a fast-growing wood that is a good raw material for pulping) and in the Pacific Northwest. Production in the Northeast has generally declined (with only the state of Maine holding its own), as it has in the North Central region.

The overall picture is presented by Lockwood's Directory for 1974 as follows: in Table 5.1.2D:

Table 5.1.2 D - Number of Pulp and Paper Mills by Pulping Process

Region	Companies (1)	Establishments (incl. HQ units)	Paper Mills (2)	Pulp Mills (Total)	Groundwood	Other Mechanical (3)	Semimechanical	Sulphite	Kraft	Miscellaneous (4)
United States	412	953	761	411	64	71	45	32	119	80
New England		146	119	43	13	2	2	3	7	16
Middle Atlantic		213	156	39	6	9	2	1	4	16
East North Central		212	173	75	12	12	9	10	7	25
West North Central		31	25	18	5	6	2	1	2	2
South Atlantic		108	91	70	4	13	12	1	33	5
East South Central		53	47	42	6	6	6	-	21	3
West South Central		59	55	47	6	9	5	-	24	3
Mountain		9	7	5	1	-	-	-	3	1
Pacific		122	88	71	11	14	7	15	18	7

[1] Subsidiaries and autonomous divisions of parent companies are counted as separate units. Total reflects elimination of duplication of names in more than one state.

[2] Includes mills manufacturing paper and/or paperboard, regardless of the number of paper machines, and regardless of whether one or more pulp mills are located at the site.

[3] Includes steam and hot water defibrated, exploded, shredded, cold soda, and chemi-mechanical wood pulp mil[illegible]

[4] Includes deinking, rag, soda, rope, flax, bagasse, and cotton linters pulp mills

Source: Lockwood's Directory, 1974

5.2 The Structure of the Industry

The paper and allied products industry (SIC 26) is a major industry in the U.S. The value contributed by it is about 1% of the GNP. In its operations, power is a major input, and the industry ranks fourth after Chemicals, Steel and Petroleum, consuming 11% of the total energy used by the manufacturing sector (see Table 5.2.1A)--requiring twice as much power and fuel as the next most important consumer, aluminum.

The rate of expansion of the industry has slowed considerably since 1970. In the fifties and sixties capacity in all sectors of the paper industry grew at an average of 4% per year. In this decade, growth has declined to 2.5%, in line with a levelling off of demand.

The paper and allied products industry consists of three major sectors: pulp production, paper and paper board manufacture, and converting these products into end-use items, such as stationery, envelopes, tissue, boxes, newsprint. Ninety per cent of the pulp produced in the U.S. moves through integrated operations from pulp to paper mills within companies or under long-term contract. Only about 10% is sold in the market. Recycling is much less important, constituting only about 20% of the input into new paper and board.

Considerable economies can however be expected, if the potential offered by increased recycling and utilization of low-grade heat sources is exploited.

The industry is generally vertically integrated from woodlands to pulp production, paper and paper board manufacture and to conversion to end products. About 70% of the total output comes from integrated operations (excepting conversion). This is shown in some detail in Table 5.2A for 1972. Concentration is likely to have further increased since then.

Lockwood's Directory for 1976 lists 406 companies in the paper

Table 5.2A: Concentration Ratios (1972)

Product	Percent of Shipments Accounted For By: 4 Largest Companies	8 Largest Companies	20 Largest Companies	50 Largest Companies
Pulpmills	43	61	85	99
Papermills, exc. Building Paper	25	40	65	86
Paperboard Mill Products	26	41	67	92
Paper Coating & Glazing	26	37	56	77
Envelopes	27	41	62	81
Bags, exc. Textile Bags	21	36	58	74
Die-cut Paper & Board	37	47	61	80
Pressed & Molded Pulp Goods	75	89	98	100
Sanitary Paper Products	65	82	94	99
Stationery	26	38	56	73
Other Converted Paper Products	14	24	42	64
Bending Paperboard Products	20	32	49	68
Setup Paperboard Boxes	10	16	29	46
Corrugated Solid Fiber Boxes	19	33	58	76
Sanitary Food Containers	41	58	80	90
Fiber Cans, Drums, etc.	52	67	80	90
Building Paper & Board Mills	47	66	95	99

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

Table 5.2B: General Statistics, 1976 Census: Pulp, Paper and Board Mills

Industry	Total#	Employees Number 000	Employees Payroll $ B	Value Added $ B	Cost, Materials, Fuels $ B	Value of Shipments $ B	New Capital Expenditures $ B	Gross Value, Fixed Assets $ B
Pulp Mills	413	15.7	.26	.97	1.09	2.06	.38	2.45
Paper Mills*	759 (Paper Mills, Paperboard Mills, Building Paper & Board Mills)	127.5	1.98	4.88	6.94	11.77	1.04	10.33
Paperboard Mills		64.7	1.02	3.13	3.64	6.72	.84	6.91
Building Paper & Board Mills		9.4	.11	.24	.28	.52	.02	.37

* Except Building Paper

Source: U.S. Department of Commerce, Bureau of the Census, Census of Manufactures, 1976, Washington, 1977 M 76 (AS)-1 and -5

#Lockwood's Directory of the Paper and Allied Trades for 1976.

industry with 935 establishments, having 413 pulp and 759 paper mills. The following table shows the companies active in the industry, according to the 1972 Census of Manufactures:

	Pulp Mills	Paper Mills	Paper Board Mills	Construction Paper & Board	Total
1972	46	194	135	45	420
1967	45	203	148	43	439
1963	34	186	146	33	399

Table 5.2B offers overall statistics from the 1976 Census of Manufactures concerning pulp, paper and board mills. According to these data, the ratio of payroll to value added in 1976 was .364, much below the (1975) national average of .475. By all the criteria presented, paper mills are the most important industry branch, followed by paper board mills. Payroll contained in the value of shipments ranges between 13% (pulp mills) and 21% (board, etc., mills), for the four industry sectors. Capital intensiveness, as measured by the value of assets (gross book value of depreciable assets) against annual shipments varies more widely, as it ranges from 71% for building paper and board mills, through 88% for paper mills, 103% for board and to 119% for pulp mills.

The highly capital-intensive nature of the paper and allied products industry is indicated by figures in Tables 5.2B and 5.2C. Table 5.2B shows fixed assets totalling about \$ 20 billion vs. value of shipments of \$ 21 billion, a payroll of \$ 3.4 billion and cost of materials of \$ 12 billion. In terms of ratio to shipments, the three criteria compare as 95%, 16% and 57%, clearly indicating the significance of capital investments.

The extent of continuing capital expenditures is indicated in Table 5.2C, which lists paper after only petroleum and chemicals in terms of new investment as per cent of sales, again emphasizing the industry's capital intensive nature.

Table 5.2C: New Investment as a Percentage of Sales, 1965-75

Product	Percentage
Paper	6.3
Food	2.5
Textiles	2.8
Chemicals	6.9
Petroleum	20.0
Rubber	6.2
Stone, Clay, and Glass	6.0
Primary Metals	5.5
Machinery, except Electrical	5.0
Electrical Machinery	4.1
Transportation Equipment	3.2

Source: U.S. Department of Commerce, Bureau of Economic Analysis, and Bureau of the Census.

According to industry sources, gross indications for investment requirements for pulp and paper mills and minimum economic size are as follows:

	$/t daily capacity	minimum econ. size, t/d
Recycling and paper mill	300,000	450
Groundwood and paper mill	400,000	500
Kraft pulp and paper mill	500,000	500

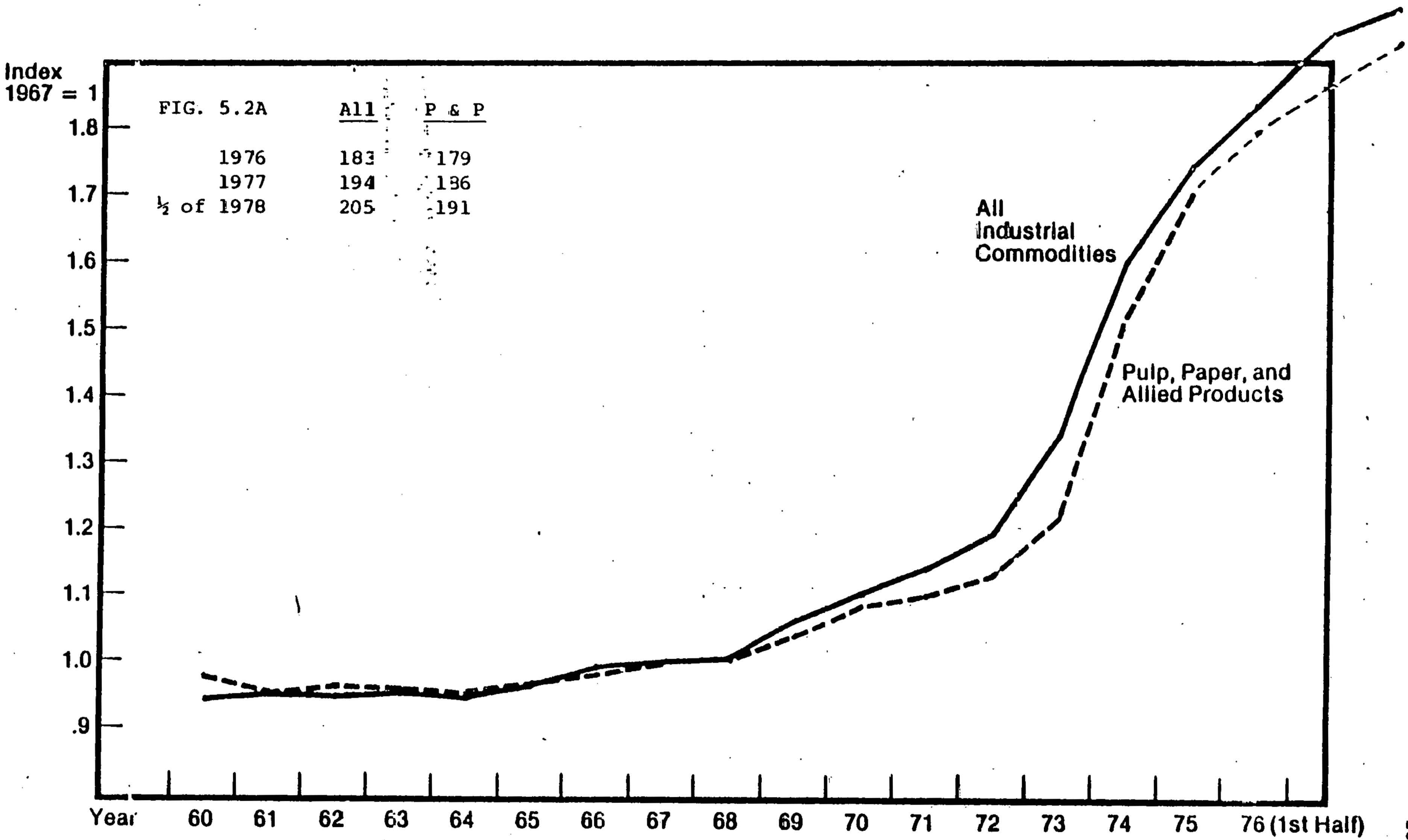
Therefore, the cost of a minimum-size plant is $135, $200 and $250 million, respectively.

Paper also ranks with other big industry on the basis of wages: it is sixth in outlays per employee after oil, transportation equipment, chemicals, primary metals and machinery.

As shown in detail in Section 5.2.3 below, paper product prices have risen very substantially in recent years, after a period of stability up to 1972. In 1973 and 1974 they increased an average of 16% per year, then holding in 1975, only to go up again in 1976 and 1977--much in line with other industrial materials. Figure 5.2A presents the record through the first half of 1978.

FIGURE 5.2A

Wholesale Price Index, Pulp, Paper and Allied Products



SOURCE: Bureau of Labor Statistics

Rising prices have generated profit margins adequate to attract new capital to permit industrial growth in line with expansion in demand.[25] Although some capital (about 15 to 20%) was absorbed by investment in pollution control equipment, these capital requirements do not seem to have affected investment practices. Retrofitting abatement machinery into existing plant has been very costly, but future additions to capacity will be brought on stream together with the required pollution controls at substantially lower cost.

The capital investment required for a pulp mill, Harris,[2] gives the following costs for a 1,000 tons per day kraft pulp mill:

Table 5.2D:

	$ Million	
Direct Costs		
Installed Equipment		
Wood preparation	7.0	
Pulping	9.4	
Washing, screening	8.8	
Bleaching	13.3	
Drying, baling	17.6	
Recovery boiler	16.4	
Auxiliary boiler	12.8	
Power generation	6.2	
Recausticizing	7.7	
Evaporation	7.0	
Effluent treatment	6.5	112.7
Services		
Water supply	2.8	
General services	4.6	
Nonprocess buildings	3.0	
Site preparation	.5	10.9
Total Direct Cost		123.6
Indirect Cost		15.8
Total Plant Cost		139.4

These costs reflect January 1974 prices. In all likelihood, these figures should be almost doubled to reflect current capital needs, without cost of land, railroad, etc. facilities. The same paper provides an idea of kraft pulp production costs applicable to early 1975, as follows: (Table 5.2E):

Table 5.2E		$ / air dried ton
Wood ($ 35/cord)		65.10
Chemicals		14.53
Pulping	1.18	
Bleaching	13.95	
Labor		47.67
Fuel		6.43
Depreciation		44.75
Repair & Maintenance materials		9.56
Property taxes & insurance		2.39
		190.43

The above data reflect order of magnitude data, which were somewhat conjectural (Author's Communication) at the time when the paper was presented.

Table 5.2F shows the financial performance during 1976 of the leading 38 U.S. and Canadian paper companies, having sales ranging from $ 140 million to $ 3.5 billion. It will be seen that the financial results have varied widely, as particularly indicated by the per cent return on equity and the debt-to-equity ratio.

The Table also provides an insight into the timberland holdings of the paper companies.

There has been a trend for paper mills to integrate back to timber resources, and for lumber mills to move forward into paper. The reason for going "basic" or for expanding the range of wood products marketed has been shown to be the capital gains treatment for timber.

On the basis of the figures obtained from Moody's, it has been shown that the leading 38 paper companies hold at least 43 million acres of U.S. timberland, as well as 48 million acres in Canada. In addition, the companies are reported to have leased about 10 million acres in the U.S. and 25 million acres in Canada. One Canadian company owns 2.4 million acres and leases 12.5 million acres in Canada alone.

Table 5.2F: Characteristics of Major Pulp & Paper Companies

	Sales $ Bill.	Profits $ Mill.	Return %	Debt: Equity	Land Holdings Acres Mill.
International Pap.	3.5	254	15.2	58%	8.5 12.9*
Georgia-Pacific	3.0	215	15.9	33	4.6 1.4*
Champion-Intern'l	2.9	103	11.0	73	11.7 4.8*
Weyerhaeuser	2.9	306	15.4	62	5.7 4.8*
Crown-Zellerbach	2.1	98	11.7	51	3.4
Boise Cascade	1.9	97	10.3	46	2.2 3.8*
St. Regis	1.7	91	10.6	40	2.5 2.9*
Mead	1.6	89	14.9	54	1.4 .4*
Kimberly-Clark	1.6	121	15.0	29	considerable
MacMillan Bloedel	1.5	23	4.6	75	considerable
Scott Paper	1.4	73	9.3	45	considerable
Union Camp	1.0	119	18.2	32	1.7
Westvaco	.92	57	13.4	48	considerable
Abitibi	.88	13	4.2	79	considerable
Domtar	.90	11	3.2	57	considerable
Gt. Northern Nekoosa	.84	58	13.5	39	2.7
Consol. Bathurst	.75	18	7.0	68	2.4 12.5*
Hammermill	.69	23	9.3	63	? ?
Potlach	.62	48	14.3	46	1.3
Southwest Forest	.55	8	5.8	133	considerable
Willamette	.55	42	n.a.	47	? ?
Reed Paper	.43	.4	.2	73	participations
Inland Container	.40	27	15.9	31	some interests
Federal Paper Board	.39	23	13.5	58	some interests
B C Forest Products	.39	26	16.1	68	? ?
Olinkraft	.34	33	15.0	28	.7
Consol. Papers	.29	22	13.2	4	see Cons. Bathurst
Longview Fibre	.26	24	15.5	0	?
Stone Container	.25	13	14.8	77	no data
Sonoco Products	.24	19	15.3	5	? ?
Alton Box Board	.24	6	7.3	54	? (Williams Co's)
Fort Howard	.23	41	24.0	0	no data
Fibreboard	.19	(34)		177	no data
Southland Paper	.19	18	12.2	57	? ?
Fraser	.18	11	10.7	42	no data (also lumber)
Canadian Cellulose	.18	15	13.9	39	no data (also lumber)
Hudson Pulp & Paper	.16	7	8.5	53	.5
Chesapeake Corp.	.15	12	n.a.	36	.35
Great Lakes Paper	.14	5	7.5	35	no data (also lumber)

Source: Pulp & Paper, June 1977 Moody's Industrials - ? = Co. not listed
No data = Moody's provides no information; (also lumber = company produces lumber products other than paper, etc., no data on holdings of timberland; * = foreign (almost always Canadian) holding

Unfortunately, in many cases Moody's does not quantify the land holdings, but indicates them to be considerable. In other cases the Handbook provides no data, but shows that the companies are also in the lumber business, permitting the conjecture that adequate forest lands are in company hands.

The significance of wood as a feedstock for paper production is illustrated by the following order-of-magnitude data:

To produce one ton of paper by	Requires tons of timber
the Kraft process	3.5
the Groundwood process	1.5
the NSSC* process	2
from recycled paper	-

The U.S. produced about 60 million tons of paper and board in 1977. The recycle rate was 21.5%, leaving about 50 million tons to be supplied from pulp.

This then represents:	Million tons of timber
35 million tons of kraft pulp	122
4.5 million tons of groundwood pulp	7
4 million tons of NSSC* pulp	8
6.5 million tons of other pulp	20e
	157

*NSSC = Neutral Sulfite SemiChemical

C. M. Cosman[3] states, "The largest paper manufacturer produced 9% of the total U.S. output. It also owns or controls some 23 million acres of woodlands. The ten top paper companies produce 45%, and the leading twenty companies 65%, of all the paper and paperboard made in the country.

"Among the major U.S. producers of recycled boxboard (in which recycle supplies the major portion of the feed), only one company has major timber holdings.... out of a total of nine companies." The significance of this point will become more evident within the context of the energy needs of virgin vs. recycled paper.

For an understanding of the industry structure, the preferential tax treatment accorded to the timber industry must be appreciated. It has determined the structure of the timber and related industries, and it has resulted in the neglect of recycling of waste paper and in the expansion of vertical integration. Significant energy savings can be made by increased recycling, which has intrinsically lower thermal needs. Also, since such operations are in urbanized areas, waste, low-grade steam can be used for additional savings.

Emil Sunley, in a paper prepared for the Joint Economic Committee of the Congress[26] presents his findings of the effect of the special tax treatment on the timber and allied industries. He points out that the timber industry receives tax subsidies in the form of three benefits:

(1) Capital gains treatment of income derived from growing timber

(2) Mismatching of income and expenses

(3) Conversion of ordinary income to capital gains.

Capital gains treatment: under the Revenue Act of 1943, income derived from the increase in the value of standing timber can be treated as capital gains. For corporations, long-term capital gains are taxed at 30%. Since most corporations pay 48% on taxable income, this presents a great opportunity to treat significant income at the lower rate. Also, it is permitted to offset net losses in timber operations in full against ordinary income (as distinct from most other such special tax treatments).

Mismatching of income and expenses arises out of the allowance that expenses incurred in growing and carrying timber (brush control, thinning, pruning, shaping trees; insect and disease control; property taxes and interest on mortgages) are currently deductible (though many of these items should properly be capitalized and added to the basic cost of timber), while income is only recognized at the time of sale.

Conversion of ordinary income to capital gains extends the preferential tax treatment to income from logging or manufacturing, e.g. pulp and paper manufacture.

The program favors large corporations, especially those integrated into vertical operations, and offers "almost nothing" to the small woodlot farmer. To derive an advantage from the 30% capital gains rate, the taxable corporate income must be above $ 25,000 (according to Sunley in 1972; now it would seem to lie at $ 59,000). This fact has enabled large companies to outbid small operators in buying timberland.

When a paper company cuts its own timber, the determination of the fair market value of the standing timber divides the total taxable income between capital gains and ordinary income, as shown in the following three examples:

(1) Assume that the corporate taxpayer is in the 50% class, cuts its own timber and merely sells the logs, and that there is no capital gains treatment, then:

Cost base is	$ 5M	for the timber
Logging costs are	7M	
Sales price is	20M	

Without capital gains

Gross income is	$ 8M
Tax is	4M
Net profit is	4M

(2) Assume the corporate taxpayer cuts and sells its own timber, and that the fair market value of the timber is $ 9 M, but the taxpayer uses the capital gains allowance: the capital gain is $ 4 M (9-5) and the ordinary income is $ 4 M (20-7-9). Then:

Capital gains of	$ 4 M are taxed at 30% =	$ 1.2 M
Ordinary income of	$ 4 M is taxed at 50% =	$ 2 M
Net profit is		$ 4.8 M

(3) Assume that the taxpayer can claim a fair market value of $ 13 M, resulting in a capital gain of $ 8 M. Then:

Capital gains of $ 13 M are taxed at 30% = $ 2.4 M
Ordinary income is 0
Net profit is $ 5.6 M

In the case of integrated operations, the selling price of timber going into pulp and paper production is a transfer price (not an arms length transaction). Therefore the company can set an artificially high price for the raw material transfer (and often has extended arguments about this with the IRS).

As is implied in the above cases, sometimes on adjacent pieces of land, an integrated large company with high profits from later manufacturing operations may claim a high fair market value for its timber to minimize the proportion of taxable income resulting from later activities. At the same time, its neighbor, a single product company with low profits, may claim a much lower fair market value for its identical timber, to lower its tax liability.

The following table shows reported capital gains as a percentage of taxable income for 1964 to 1969 as distilled by Sunley[26] from four large timber companies. This "average large firm" has obviously minimized its tax liability by having almost 100% of its taxable income reported at the preferential capital gains rate.

Year	(1) Taxable Income, $ M	(2) Capital Gains, $ M	(3) Proportion (2) as % of (1)
1964	50	46	92
1965	50	49	98
1966	48	49	103
1967	42	50	120
1968	90	76	84
1969	96	101	105

The foregoing brief review of the preferential tax treatment of the timber and paper industry will help to explain the industry structure. Increasing vertical integration has brought timber companies into the paper industry, and induced paper manufacturers to move into pulp production and timberland acquisition. It is also the likely root cause of the neglect of waste paper as a resource (see also Section 5.2.4). The initial intent of the Congress in allowing special tax treatment has been converted into a bonanza for the timber and allied industries, while the aim of the Congress to maintain an adequate timber resource has become an obvious objective of enlightened self interest of the industry, not requiring the prod of tax benefits.

The foregoing description of the industry structure might suggest that it is highly profitable. However, data given by the CWPS study[25] indicate that profit margins and return on shareholders' equity have not been better than those for all manufacturing, except in the most recent past (which also saw a decline in plant expansion). The poor performance with respect to return on equity may well be attributable to heavy investments made, while low profitability was largely due to the effect of price controls 1970 through 1972. Figures 5.2B and 5.2C show the earnings record in comparison with the record for all manufacturing industries.

FIGURE 5.2B

Return on Shareholders' Equity for the Paper and Allied Products Industry VS. All Manufacturing

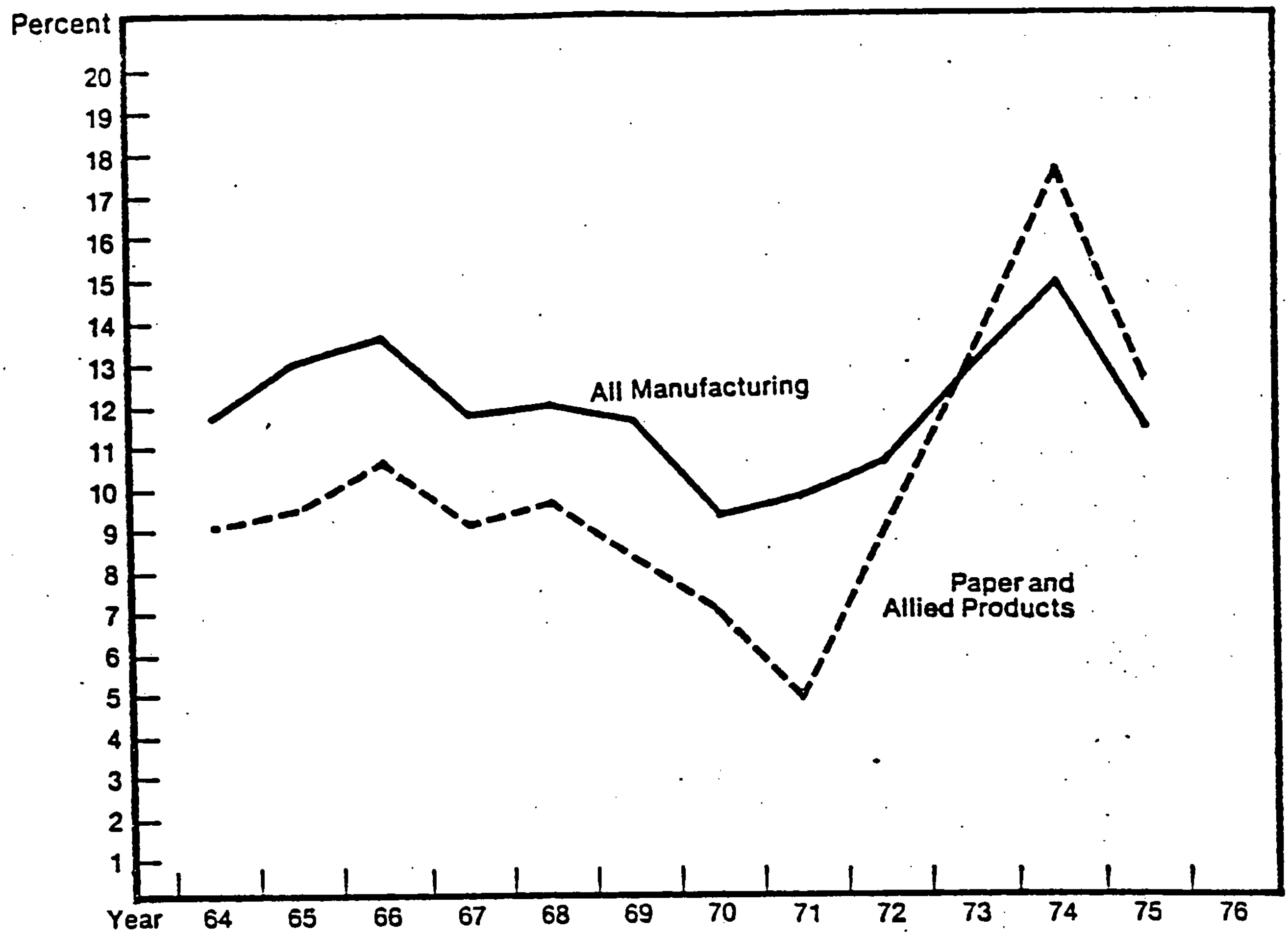
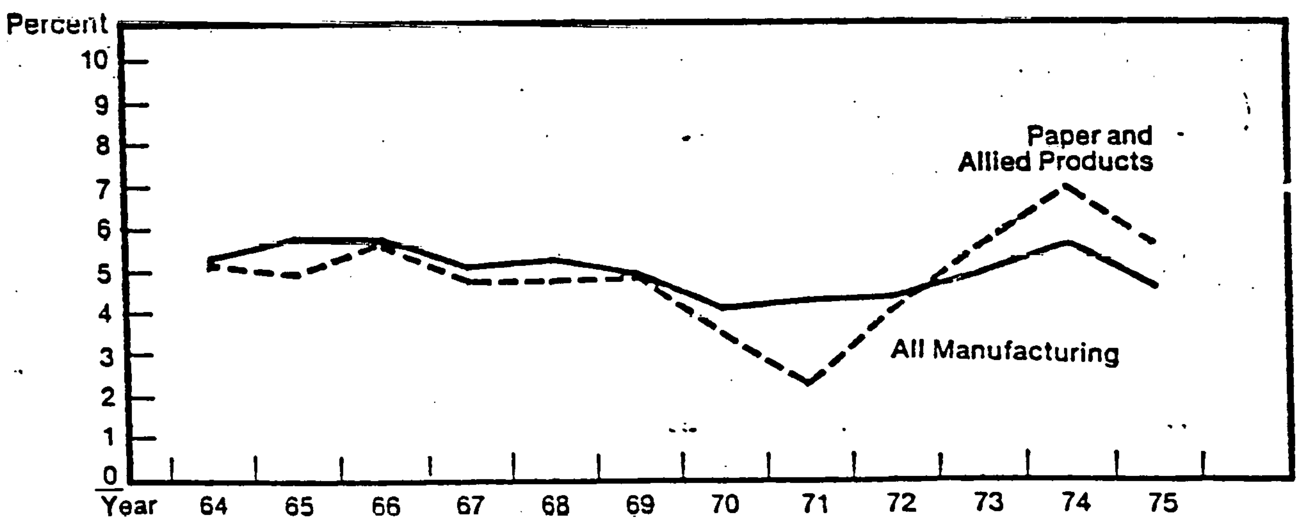


FIGURE 5.2C

Profit Margins for the Paper and Allied Products Industry VS. All Manufacturing



NOTE: FTC changed its accounting methods in the fourth quarter, 1973.

SOURCE: Quarterly Financial Report, Federal Trade Commission.

5.2.1 Energy and the Paper Industry

According to the American Paper Institute (API), the paper industry is the fifth largest consumer of purchased energy in the US. and the largest consumer of fuel oil. Almost one-half of total energy consumption comes from the industry's own process wastes: spent pulping liquors, bark and hogged wood. In 1976 non-fossil fuels provided 44.6% of the total BTU consumption, up from 41.1% in 1972 and 42.6% in 1975. (Self-generated hydro power and other electricity produced from fossil fuel supplied another 1.5% of total needs in 1972 and 2.1% in 1975.)

The industry has established a mechanism for self-policing by submitting periodic reports on its energy consumption to the API. The target set by the industry is a 20% saving of purchased energy by 1980. So far a reduction of about 15% has been achieved, making adjustments for add-ons required because of environmental regulations and other changes vs. the base year of 1972.

API's ranking of the industry as fifth most energy-intensive industry in terms of purchased energy is supported by data provided by the Annual Census of Manufactures:[27]

	10^{15} BTU
Chemicals and allied products	4.0
Primary metal industries	3.4
Petroleum and allied products	1.5
Stone, clay, glass products	1.4
Paper and allied products	1.3
Food and kindred industries	1.2

The above figure agrees with industry data, relating to purchased energy. When allowance is made for the consumption of self-generated energy, the paper industry is probably the third or fourth largest industrial user of energy (oil and coal can also be expected to provide considerable in-house supplies).

According to a study prepared for the Federal Energy Administration, the ranking of energy consuming industries in 1974 was as follows:

Table 5.2.1A: Energy Consumption by U.S. Industry

	Total Consumption 10^{15} BTU
Total Manufacturing	26.0
Chemicals	5.94
Steel	3.76
Petroleum	3.27
Paper	2.82
Aluminum	1.39
Cement	.59
Glass	.34

Source: Energy and Environmental Analysis, Inc., Study for FEA

Energy consumption and self-generation by the paper industry is presented in Table 5.2.1B, which summarizes data contained in other tables in this report. It will be seen that there has indeed been a noticeable increase in the use of internal energy sources. Much remains to be done, however, because there is very little energy reclamation in some of the more antiquated pulp mills as compared to a 95% recovery rate reported for some of the newest installations.

Table 5.2.1B presents overall the following power consumption figures:

	1972	1975	1976	1977
Total Energy, 10^{15} BTU	2.357	2.070	2.303	2.402*
Paper & Board Production, 10^{6} t.	59.5	52.4	59.5	60.8*
Million BTU / ton	39.6	39.5	38.7	39.5*
Purchased Energy, 10^{15} BTU	1.425	1.210	1.332	1.380*
Net Energy Consumed, Million BTU/t	23.9	23.1	22.4	22.7*

*preliminary

Specific consumption in the production of paper and board indicates an overall decline through 1976, followed by a slight upturn in 1977--which may be due to the data being only preliminary.

Details on energy consumption by the U.S. pulp and paper industry are given in Table 5.2.1C. The data show an increase in self-generated power power from 39.5 to 42.5% between 1972 and 1977. The most important change in fuel usage was the decline in natural gas consumption, which dropped from almost 20% of total energy use to about 13%. Consumption rates of coal and oil kept level, while those for electricity increased from about 10 to 12%, for hogged fuel from 2 to 3.6% and for spent liquor (i.e., recycle in the production of kraft pulp) from about 32 to 33%.

It should be mentioned that at least one knowledgeable industry observer expressed some doubts concerning the accuracy of details in the energy statistics, as presented. While a consumption of 2.4x 10^{15} BTU (2.4 quads) or about 3% of the nation's <u>total</u> energy requirements seems enormous, it is supported by Canadian figures, which show energy purchases of the pulp and paper industry to be 4.1% and total energy use by it to be close to 7% of all the energy consumed in Canada. In fact, paper is the largest single Canadian industrial consumer.

The pattern of fuel consumption is shown in Fig. 5.2.1A, which analyzes the regional distribution in terms of fuel use by the U.S. paper industry. It is clear that historically the delivered cost of fuels dictated the preference of use and the design of plants as reflected in the use pattern as between fuel oil, gas, and coal. Now that the economics and national perceptions require a change, time will be needed to make the needed adjustments.

Substitution of coal or wood for oil and gas is expensive. There are modifications needed in boiler design and the rating, i.e., steam output, is likely to decrease, particularly where wood is substituted. When coal replaces oil or gas, environmental concerns require modifications for capturing sulfur and fly ash (however, recovery of S can be an asset in a kraft pulp mill). Both coal and wood require new burner and

Table 5.2.1C: U.S. Pulp, Paper and Paperboard Industry Estimated Fuel and Energy Use

	1972		1975		1976		1977	
	10^{12}BTU	%	10^{12}BTU	%	10^{12}BTU	%	10^{12}BTU	%
Purchased								
Electricity	271	9.8	268	10.5	323	11.6	347	12.2
Steam	22	.9	16	.8	18	.8	20	.8
Coal	222	9.4	174	8.4	212	9.2	223	9.3
Fuel Oil*	467	19.8	438	21.1	483	21.0	506	21.1
Fuel Oil**	20	.8	14	.7	18	.8	17	.7
LPG	2	.1	1	-	2	.1	1	-
Natural Gas	462	19.6	348	16.8	328	14.2	318	13.2
Other Energy	#		1	-	3	.1	2	.1
Energy sold	(41)		(50)		(55)		(54)	
Total	1,425	60.5	1,210	58.5	1,332	57.8	1,380	57.4
Self-generated								
Hogged Fuel+	45	1.9	56	2.7	76	3.3	86	3.6
Bark+	103	4.4	83	4.0	95	4.1	94	3.9
Spent Liquor	748	31.7	676	32.6	754	32.7	797	33.2
Hydropower	26	1.1	27	1.3	28	1.2	28	1.1
Other	10	.4	18	.8	18	.8	17	.7
Total	932	39.5	860	41.5	971	42.2	1,022	42.5
Total Energy	2,357	100.0	2,070	100.0	2,303	100.0	2,402	100.0

* = Residual Fuel Oil
** = Distillate Fuel Oil
\# = Insignificant
\+ = 50% moisture content

10^{12} is million millions, or trillion

Paper and Paperboard Production was	Million tons in	
	59.5	1972
	52.4	1975
	59.5	1976
	60.8	1977

Source: American Paper Institute, Annual Capacity Survey, New York, 1978. Recalculated on the basis of 1 kwh = 10,000 BTU.

fuel preparation systems.

The foregoing discussion relates only to the consumption of energy by the paper and allied industries. In addition, energy is consumed in the harvesting of timber. This energy expenditure amounts to about 350,000 BTU per ton of green roundwood, as is described in some detail in Section 5.3 below. The total energy requirements arising from this factor are accordingly in the order of 55×10^{12} BTU, about 2% of total needs of the industry. This may compensate for transportation and collection energy requirements involved in the collection of waste paper which may travel about 100 miles for an equal expenditure of energy.

Wood is ranked as the lowest-value fuel, but wood waste can be burned to recover its heat value. Similarly, waste paper contains some of the investment in heat value made when wood was converted to paper. It can be recycled with a very considerable saving in terms of energy consumption over paper made from virgin raw material. And, of course, the potential use of paper as fuel is merely postponed by recycling.

The average consumption of purchased energy per ton of paper industry product is shown in Table 5.2.1D. The largest energy consumers are Printing and Writing Papers, and Tissue, both of which groups require extensive bleaching; followed by newsprint, which uses energy-intensive groundwood pulp, and Combination Board, which requires a lot of heat for drying the heavy stock. Linerboard, Construction Paper and Board, and Recycled Boxboard consume relatively little energy because they are made from a heavy input of unbleached Kraft and recycled paper. Dissolving pulp requires heavy bleaching at the pulp mill and much of it goes into chemicals, very little into high-grade paper.

Table 5.2.1D: Average Consumption of Purchased Energy in the Production of Paper and Paperboard

Production of	Purchased Energy for Pulp M BTU/t	Paper M BTU/t	Total M BTU/t	Recovered Energy M BTU/t	Comments
Newsprint	13	14	27	3	Mainly electricity
Printing & Writing Paper	11	18	29	13	
Packaging, Converting, etc.	6	18	23	13	Usually integrated operations
Tissue	10	19	29	11	
Linerboard	4	14	18	14	
Corrugating Medium	11	14	25	1	
SBS Board	12	14	26	15	
Construction Paper & Board*	4	14	18	-	
Other Combination Board	9	18	27	4	
Dissolving Pulp	13	8	21	17	
Recycled Boxboard**	4	18	22	-	

* 35% Wastepaper
** 100% Wastepaper, 4 M BTU purchased for raw material de-inking.

Adapted from data presented in Arthur D. Little[15]

Detailed data for the consumption of fuel and energy have been developed in the following sections. A test has been run in Appendix A to determine the approximate accuracy of the overall net energy consumption figures adopted, against real world energy statistics as developed by the industry. It was found that these figures seem quite fairly to reflect the reported average energy consumption by U.S. pulp and paper manufacturing.

The following Table 5.2.1E summarizes the apparent net energy consumption, representing average current U.S. practice in the paper industry:

Table 5.2.1E: Apparent Net Energy Consumption in Pulp and Paper Manufacture

Pulp*	M BTU/t	%, Electrical
Kraft	8	75
Sulfite	7.5	60
Groundwood	14	100
Semi-chemical	6.5	80
Thermo-mechanical	21	100
Other	7	?
Waste Paper Preparation	4	80
Bleaching***	6-10	80

Paper & Paperboard**	M BTU/t
Newsprint & uncoated groundwood	14
Printing, writing, etc.	18
Tissue	19
Packaging & Converting	18
Linerboard	14
Corrugating medium	13
Solid Bleached Sulfate Board	14
Recycle Boxboard	18
Construction Paper & Board	14

*Pulp: from data in Section 5.3.1
**Paper & Paperboard: from Section 5.3.2 and Appendix A
*** Including reagents

Adapted from Arthur D. Little[9]

Individual plants in the industry will have energy consumption rates that are greatly at variance with the figures given above. Cogeneration of power and process steam is general industry practice, except for very old or very small mills. The most modern integrated mills consume relatively little outside (purchased) energy, making maximum use of fuel values contained in bark and other wood wastes, as well as the energy available in materials streams within the pulp and paper-making processes. In the paper-making process the power frequently is a steam turbine drive, rather than electric motors, which is said to result in some energy economies.

The modern practice of harvesting the total tree can fully cover the thermal needs of a pulp and paper complex and possibly produce an excess of electricity.

In the past, a major impediment to the generation of power in excess of normal pulp and paper mill requirements appears to have been the reluctance of the industry to feed excess power into the local grid. Public service commissions might then involve the company in legal tangles and problems which the industry would rather avoid. This has recently been alleviated by the Public Utility Regulatory Power Act of 1978, which exempts non-public utility power generation from the record-keeping and regulations to which public utilities are subjected.

As pointed out in the section on recycling, energy savings in the recovery and reuse of waste paper are quite substantial. A major incentive is also relief for municipal waste disposal problems. The following calculation looks at the effect of raising the 1977 waste paper recovery rate from the 21.5% actual to 30% and 40% (as it was in the 1940's and as it applied to some countries; see Table 5.2.4B). These increased recoveries translate into a reduction in the demand for pulp of 5 and 11 million tons, respectively, and a corresponding increase in waste paper use. According to estimates shown in Section 5.2.4, a 40% recycle rate is entirely possible.

The energy implications are on the basis of a weighted average of energy consumption, as shown above in Table 5.2.1D. Consumption of purchased energy averages about 23 million BTU per ton in the production of paper from virgin raw material, 13.5 million BTU per ton when waste paper is recycled. Therefore the following savings can be achieved:

<u>1977 Paper Industry Consumption of Purchased Energy in 10^{12}BTU (= T BTU):</u>

Recycle Rate %	Waste Paper Consumption Mt	T BTU	Total T BTU	Savings T BTU	Oil Equivalent M bbl*
21.5	12.7	190	1,380		
30	18	258	1,334	46	7.7
40	24	339	1,279	101	16.8

* @ 6 million BTU/bbl.

It will be seen that the savings will be quite impressive. However, simply on grounds of land use and materials effectiveness, it seems inefficient to cut 150 million tons of tree logs when either 134 million

(30% recycle) or 115 million tons (40%) will do.

Another great incentive to recycling could be the possibility of locating large paper-making plants, such as newsprint or paperboard mills, close to market. Such a location will substantially reduce haulage and also afford the opportunity for integrating the operation of the paper mill with the utilization of low-grade steam.

In essence, a paper mill is a large condenser, and combining it with a power station affords the possibility of using the low-pressure, tail steam and returning the condensate to the utility. Such an idea has apparently been realized by Garden State Paper in their Pomona, CA, paper mill.

However, such concepts generally meet with resistance by both the conventional paper industry and by the partner industry. Government can stimulate such interaction and provide aid in easing investment implications that are necessary to insure satisfactory operations on both sides when such disparate partners as electric power and paper manufacture are in harncoo.

Savings can become quite substantial when such practice becomes widespread. At present, in the production of 1 ton of paper 2,900 lb. of water are removed by heat, requiring about 3.7×10^6 BTU. If this quantity were made available from waste heat from power stations, refineries, chemical or metallurgical operations, it would greatly ease the energy economy of paper manufacture.

If the incremental 5 or 11 million tons of recycled paper were so processed, then an additional 19 or 41×10^{12} BTU, respectively, could be saved per year. The aggregate savings would then be 40 and 88×10^{12} BTU, and in terms of oil equivalence 7 million and 15 million bbl., respectively.

Since such savings can accrue also to paper produced from pulp, the

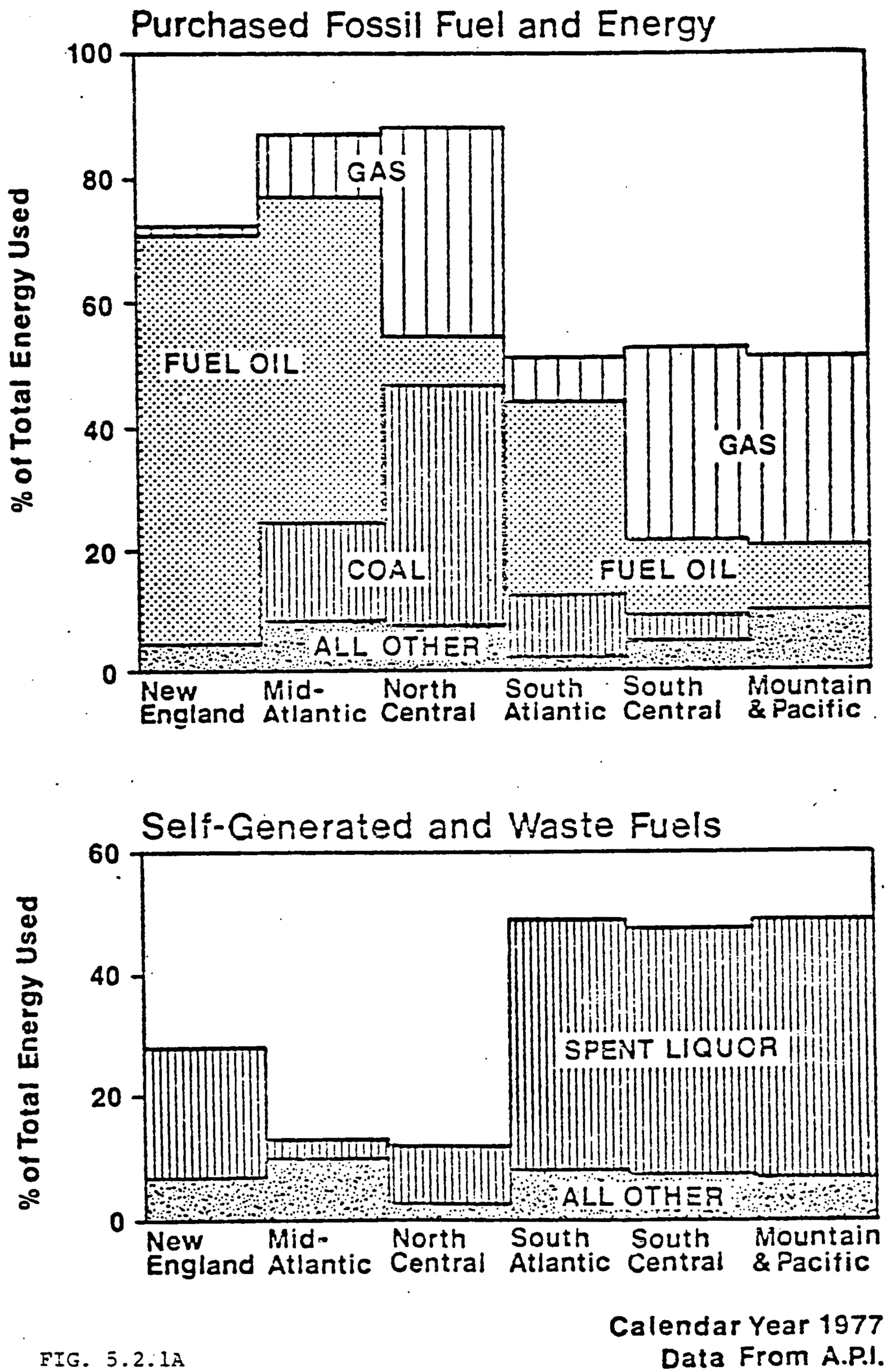


FIG. 5.2.1A

Source: Institute of Paper Chemistry, data from A.P.I.

higher figure has not been used in establishing the energy advantage of recycling. It must however be borne in mind that such arrangements are probably more likely to be made for major paper-making operations, predidated on recycling, because of their likely location. Conversely, operations based on the processing of pulp might be able to make increased use of low-grade heat, such as is offered by a geothermal source. If all paper production were based on the use of low-grade heat from byproduct or waste steam, total savings would be equivalent to 37 million bbl. of oil.

Large savings of purchased energy can additionally be effected if the industry can be persuaded to operate its integrated pulp and paper mills under conditions of maximum fuel efficiency. While it should be understood that Kraft pulp quality and energy recycle are inversely related to pulp yield (i.e., the highest grade yields about 35% from pulp, and the lowest only 55-58%, the balance going into recycle), nevertheless industry observers believe that the process can be made substantially energy self-sufficient for all grades.

When apparent average consumption of purchased energy by U. S. kraft mills (8 million BTU per ton of pulp) is halved, total savings of energy would be 1.4 x 10^{14} BTU. Translating these savings into their oil equivalence, they would contribute in the order of 23 million bbl. of oil to the U.S. energy economy.

As implied by this calculation, the discrepancy that exists between the fuel efficiency of the best plants, even compared with the industry average, is quite striking (see Section 5.3.1.4). Some industry observers point out that greater fuel economies pay out well, but that in many cases management is satisfied with profitability as it is at present, and sees risks in innovations and changes that might affect near-term earnings.

Nevertheless, as in all energy-intensive industries, a considerable effort is being made to reduce energy consumption, and to shift from critical to less critical fuels. The industry has set itself an impressive target for reducing consumption of purchased energy by 20% in 1980 vs. 1972 (with due allowance for incremental consumption of fuel due to EPA regulations.

On the other hand, some observers (Thermo-Electron[1]) point out that only one-half of hogged fuel and bark available to the industry in 1972 was used for heat generation, the other half going to waste.

Some misgivings are being expressed with the actual data on energy requirements as presently developed, and better, more reliable energy consumption data will be obtained on the basis of a systems analysis being undertaken by the Institute of Paper Chemistry at Appleton, Wisconsin, so that actual energy flows within the industry can be more firmly determined. This project should begin to yield results in about two years.

Also, the Pulp and Paper Research Institute of Canada has worked on a computer model to evaluate the Canadian pulp and paper industry's materials and energy flows. (Its work has been interrupted by other problems, but it is now being resumed.)

Some other approaches taken by the industry have been described in this and in the following sections. It has been indicated in this study that massive energy savings can be achieved by

(1) increased recycling of waste paper ,

(2) use of heat now wasted by other industries (or from geothermal sources)

(3) improving the efficiency of existing kraft pulp mills to achieve a better national average net fuel consumption in this highly energy intensive process.

Beyond these targets, several suggestions have been made that merit brief discussion at this point.

Whole tree harvesting is likely to offer sufficient byproduct fuel to cover the entire thermal needs of a pulp and paper mill complex, with or without lumber operations. If adequate boiler capacity is provided (wood-fired boilers are more expensive than oil- or coal-fired ones) a surplus of power may be achieved--at least intermittently. Under new legislation, this excess can be fed into the public grid without the legal impediments that formerly applied--but the price that the public utility is willing to pay for this power is likely to remain a source of conflict.

A Canadian suggestion relates to the use of the pulp refiners as a sort of governor to absorb excess electric power when available, instead of feeding the power into the grid. This involves over-sizing refiner capacity and providing downstream storage to accommodate the product overrun. (Under U. S. conditions this power can now flow into the grid.)

The Institute of Paper Chemistry favors the saving of thermal energy by increasing the fiber content in the Foudrinier feed, thereby reducing the volume of water that must be recycled under heavy power inputs for pumping. Research on this approach is being pursued by many organizations.

The Institute also stresses the importance of mechanical removal of water in the paper-making process. As the wet stock passes through the first sets of rolls, water is being squeezed out of it without expenditure of heat. Apparently good results have been achieved on a bench scale model, but no translation into commercial or pilot scale has been possible. If the experimental results of reduction of moisture down to 33% could be achieved by mechanical means, then only .5 lb. of water would have to be removed by drying per lb. of product, saving about 2.5 million BTU per ton of paper.

Although converting paper to consumer product represents probably only 5% of the industry's total energy needs, some smaller, but not inconsiderable savings can also be achieved by subjecting these processes to scrutiny. The Institute has for example developed a process in which linerboard is converted to corrugated boxes without direct use of heat. This is said to save about 1 million BTU per ton. At an annual production rate of 20 million tons, apparent savings would be $20x10^{12}$BTU per year.

While considerable work is being done by the industry and research organizations to make the pulp and paper industry more energy efficient, much more can be achieved by government action to provide a climate that will stimulate industry to take the steps to make the investments needed for substantially greater fuel economies.

Recommendations:

* Government should support improved materials effectiveness in the pulp and paper industry, which will also result in substantial fuel economies, especially by promoting recycling and "whole tree harvesting"
* Disallowance of special tax treatment for capital gains on standing timber will eliminate, in future, preference for virgin raw material and stimulate the use of recycled paper
* Support should be given to industry to make full use of all values contained in timber, including the harvesting of the entire tree, thereby maximizing power generation by pulp mills from wood values now frequently wasted
* Support should be given to municipalities to promote source separation of paper to improve recycling and alternatively use of paper as supplemental fuel in power generation (it is of great importance that this matter be

fully and promptly investigated and discussed before a commitment is made by municipalities to burn the entire municipal solid waste without requiring source separation of potentially recyclable paper, such as newsprint, magazines and stationery).

* Studies might be needed to determine why the U. S. had considerably better recycling rates in former decades and what action foreign governments have taken to improve the reuse of waste paper

* Further study is suggested to develop the concept of using low-grade steam, e.g., from power plants or geothermal sources, to supply the needs of paper mills for process heat requirements. This approach might well need government stimulation to effect energy savings, in view of institutional inhibitions.

* Encouragement now provided through industry efforts to expand its "in house" energy base through increased power and steam generation from waste products, through greater energy economy, through conversion from critical to more expendable fuels, through research into energy-saving process modification--should be further expanded.

* Technology transfer from bench scale research and pilot plant operations to commercialization should be facilitated by government underwriting some of the financial risks, either by direct funding or special tax incentives.

5.2.2 Volume of Production of Pulp

Production of pulp by major grades from 1920 to 1977 is given in Table 5.2.2A, below:

Table 5.2.2A: Production of Pulp in the U.S. by Major Grades, 1920-1977, in Millions of Tons

Year	Kraft	Sulphite	Groundwood	Semi-chemical	Other	Total Pulp
1920	.2	1.6	1.6	---	.5	3.8
1925	.4	1.4	1.6	---	.5	4.0
1930	1.0	1.6	1.6	---	.5	4.6
1935	1.5	1.6	1.4	.1	.5	4.9
1940	3.7	2.6	1.6	.2	.8	9.0
1945	4.5	2.4	1.8	.3	1.2	10.2
1950	7.5	2.8	2.2	.7	1.6	14.8
1955	11.6	2.3	2.7	1.4	1.8	20.7
1960	15.0	3.3	3.3	2.0	1.7	25.3
1965	21.1	3.6	3.9	2.9	1.7	33.3
1970	29.4	3.3	4.4	3.3	1.8	42.2
1975	29.2	3.5	4.4	3.2	2.8	43.1
1976	33.6	3.4	4.8	3.5	3.1	48.4
1977	34.8	3.5	4.5	3.9	3.0	49.7

Source: Guthrie, J. A., An Economic Analysis of the Pulp and Paper Industry, Washington State University Press, 1972--updated from Census date.

The growth of pulp production in the U.S. during the past half century has been at a compound rate of 5.5% p.y. The tremendous growth of Kraft pulp production (about 9% p.y.) is seen as against the relatively static production history of virtually all other pulp production processes, except semi-chemical.

U.S. paper production has grown similarly by about 4.8% annually over the past 50 years, as is shown in Table 5.1.2.

5.2.3 Markets

The demand for paper and paper products has historically been related to real GNP. The demand for paper varies directly with economic activity on the national level.

The statistical record for the U.S. market for paper and paperboard production, 1961-1977, is presented in Table 5.2.3A. The average growth of paper consumption in the U.S. has been about 4.8% per year during this century, but in recent years it was only around 3%. The most important market segments are discussed below, substantially following the North America Profile 1978 of Pulp & Paper, June 1978.

5.2.3.1 Newsprint

U.S. production of newsprint has grown from 2.1 million tons in 1961 to 3.5 million tons in 1977, an apparent average rate of 2.9% per year.

In addition to newspapers, this grade is also used for letterpress or offset printing, advertising, government publications, comic books, etc.

U.S. newsprint consumption has been in the 10 million ton per year range for some time, but reached a new high with 10.3 million tons in 1977. It is expected that consumption will spurt by 4.5% this year and then continue more slowly, probably at about 3% per year. There has been a reawakening of interest in newspapers and newspaper advertising in the U.S.

Prices have gone up from \$ 152 per ton in 1970 to \$ 305 in 1977, or from \$ 138 to \$ 156 in constant 1967 dollars, based on the wholesale price index.

The U.S. buys about 63% of its newsprint from Canada, but U.S. companies have expanded their plants and the Canadian market share is likely to decrease slightly. Total 1977 North American capacity is 14.3 million tons, and the top five companies have 43.2% and the top ten 63.3% of it.

Table 5.2.3A: U.S. Production of Paper and Paperboard 1961-1977. Millions of sh. tons.

	1961	1965	1970	1974	1975	1976p	1977p
Total Paper	15.8	19.2	23.4	26.7	23.3	26.6	27.3
Printing, writing, etc.	9.2	11.3	14.4	16.9	14.6	16.8	17.4
Newsprint	2.1	2.2	3.3	3.4	3.5	3.4	3.5
Groundwood paper	.9	1.0	1.2	1.4	1.3	1.6	1.5
Coated printing & c.*	2.1	2.8	3.3	4.0	3.3	4.0	4.3
Book paper, uncoated	1.7	2.1	2.6	2.9	2.4	3.0	3.0
Bristols**	.7	.9	1.0	1.2	.9	1.0	1.0
Writing, etc., nec.*	1.8	2.3	2.9	4.1	3.2	3.8	4.0
Packaging & industrial c.*	4.3	5.0	5.4	5.7	4.8	5.8	5.7
Unbl.* Kraft pkg* & ic.*	3.0	3.5	3.8	3.9	3.4	4.1	4.0
Other pkg* & ic.,* etc.	1.0	1.2	1.2	1.2	1.0	1.2	1.2
Special industr. paper	.3	.4	.4	.6	.4	.5	.5
Tissue & other machine cr.*	2.3	2.9	3.6	4.0	3.8	4.0	4.1
Sanitary paper	2.1	2.7	3.4	3.8	3.7	3.8	3.9
Other tissue	.2	.2	.2	.2	.2	.2	.2
Total Paperboard	16.5	20.8	25.5	28.0	24.3	27.6	27.9
Solid woodpulp furnish	9.5	12.7	18.5	20.8	18.5	20.8	20.8
Unbl.* Kraft pkg* & ic.*	5.7	7.8	11.6	13.0	11.6	13.4	13.3
Bleached pkg* & ic.*	1.8	2.3	3.4	3.8	3.4	3.7	3.7
Semichemical paperboard	2.0	2.7	3.5	4.0	3.5	3.7	3.8
Combination furnish	7.0	8.1	7.0	7.2	5.8	6.7	7.0
Comb* Ship'g Cont*board	1.5	1.9	1.5	1.8	1.1	1.3	1.6
Comb* bending	3.0	3.4	2.7	2.4	2.1	2.4	2.4
Comb* nonbending	1.0	1.0	1.1	.8	.7	.8	.8
Gypsum linerboard	.6	.7	.8	1.0	.8	2.1	1.8
Special pkg* & ic.*	.8	1.1	.9	1.3	1.1	2.1	1.8
Wet Machine Board	.16	.14	.14	.14	.11	.10	.10
Construction paper & board	3.2	3.9	4.3	5.1	4.7	5.2	5.5
Construction paper	1.4	1.6	1.6	1.8	1.6	1.7	1.8
Insulation board	1.1	1.2	1.3	1.3	1.2	1.4	1.4
Hard pressed wood fiberboard	.8	1.1	1.4	2.0	1.8	2.1	2.3
Total, All Grades	35.7	44.1	53.3	60.0	52.4	59.5	60.8

* c. = converting nec. = not elsewhere classified
ic. = industrial converting unbl. = unbleached pkg. = packaging
cr. = crepe Cont. = container Comb. = Combination
** (85% or more bleached fiber)

Source: Bureau of Census--1965 data regrouped to new definitions. Data courtesy of American Paper Institute.

5.2.3.2 Coated Paper

The U.S. market for coated paper has gone from 2.1 million tons in 1961 to 4.3 million tons in 1977, an average growth rate of about 4.4%.

Two-sided coated papers are used for printing, one-sided for labelling. There are five grades of coated printing paper, magazine stock being the lowest, accounting for 53% of coated paper production.. Demand has exceeded supply during 1978 and No. 5 stock had to be imported.

Prices have increased from $ 285 ($ 211) per ton in 1973 to $ 490 ($ 250) in 1977 (constant 1967 dollars) for No. 5 grade (34-36 lb.) and recently have gone up further to $ 560 per ton.

Markets are 49% for magazines and periodicals, 33% commercial printing, 11% labels and wraps and 6% for books.

U.S. 1978 capacity is 4.4 million tons, 45.7% of which can be supplied by five companies, 76.4% by ten.

5.2.3.3 Uncoated Printing and Writing Papers

The U.S. market for uncoated printing and writing papers has increased from 3.5 million tons in 1961 to 6.7 million tons in 1977, i.e. an apparent average growth rate of about 4.0%.

Uncoated printing and writing papers should contain no more than 25% of mechanical pulp in their mix, and they include uncoated book and printing as well as writing grade, specifically offset, tablet, envelope, business papers, (bond, ledger, mimeo, duplicating), forms bond, cover and text.

Although 1977 sales had improved, they did not reach the level of 1973/74, the record years.

As shown in the graph, U.S. capacity has outpaced demand. Prices are complex for this sector and a composite is used, which shows a price increase in constant dollars (based on the wholesale price index with a 1967 base). It went from 113.1 in 1970 to 162.3 in 1976 and 169 (e) in 1977.

The markets are 25% writing, copying and duplicating, 21% forms bond, 19% offset and sheet printing, 11% offset web printing, 8% envelope, 5% tablet, 4% miscellaneous book and 7% body stock.

1978 U.S. capacity for uncoated printing and writing paper is 7.9 million tons, of which 5 companies have 36.4% and the 10 largest companies have 62.9%.

5.2.3.4 Tissue

The U.S. market for tissue has risen from 2.3 million tons in 1961 to 4.3 million tons in 1977 at an apparent growth rate of 3.6% per annum. In recent years the growth rate has been rather slower, i.e. about 2.2%.

The market is composed of facial (8%), bathroom tissues (39%), paper napkins (11%), towels (32%) and (10%) stock for other sanitary materials, wadding, and wipers, as well as waxing, wrapping and miscellaneous tissues. Typical weights are 14 lb. per 3,000 foot square for toilet tissue and 33-39 lb. for towelling. Wholesale price indices show rising trends from 108.9 in 1970 to 236 (e) in 1977.

U.S. capacity in 1978 is 4.2 million tons, of which 5 companies have 60.2%, 10 companies 80.7%.

5.2.3.5 Packaging and Industrial Papers

The U.S. market for packaging and industrial papers reached 5.6 million tons in 1977 from 4.3 million tons in 1961, an apparent average growth of 1.5%. Between 1970 and 1977 production has grown by only .7% on the average per year.

This grade comprises unbleached (70%), bleached (20%), packaging and wrapping, shipping materials, sacks, glassine, greaseproof and parchment papers, etc., as well as special industrial papers such as absorbent, cable, electrical and vulcanized fiber papers, contributing only 10%.

In this sector substantial inroads are being made by plastic materials, substituting for paper-based products.

Wholesale price indices for this group of paper products show an increase from 117.6 in 1970 to 214 in 1977 (e) for wrapping papers, and 106.9 to 170 (e), resp., for bags and shipping sacks.

U.S. 1978 capacity is 6.1 mt p.y. for this sector, of which the five largest companies control 42.7% and the ten largest 61.3%.

5.2.3.6 Linerboard

The U.S. market, including export, for linerboard was 12.6 million tons in 1977, up from 5.6 million tons in 1961, an apparent growth rate of 4.5% per annum on the average. But since 1970, the rate has been at only 2.9% per year.

Unbleached linerboard is made in a wide range of weights, ranging from 42 to 90 lb. per 1,000 foot square. The major end use for this material is container board. A small amount is made from recycled fibers (not here included).

Linerboard prices went from $ 117 per ton in 1970 to $ 205 in 1978, in current dollars.

The producers of linerboard are vertically integrated into the production of corrugated containers and only about 20% of production goes to independent box manufacturers. Corrugated container production is highly competitive and the largest market share is taken up by Container Corporation, International Paper and Weyerhaeuser, each of which has 6%. In the U.S. 1977 capacity of 14 million tons, the five largest companies controlled 37.8%, the ten largest 61.7%.

5.2.3.7 Corrugated Medium

U.S. production of corrugated medium consists of two grades, one made from semi-chemical pulp and one from recycled fiber. In 1977 these grades weighed as 80% and 20%, respectively. Since 1970 production has increased at an apparent average rate of 2.4% per year.

For each 2.2 tons of linerboard one ton of medium is required, and prices for this material are generally $ 10 below linerboard.

U.S. 1978 capacity is 6.4 million tons and the leading five companies have 28%, the first ten 47% of this capacity.

5.2.3.8 Recycled Boxboard and Paperboard

There are three major categories in this group, which had a 1977 production of 7.3 million tons: first, with 50% of the market, is folding boxboard (mostly clay coated), followed by setup boxboard (generally uncoated) and paperboard.

Between 1970 and 1977 production increased by .2% per year.

U.S. capacity is 9.1 million tons, with the largest five companies having 28.4% and the ten largest 42.1% of it.

5.2.3.9 Construction Papers and Board

This group, with a 1977 production of 5.5 million tons, includes under construction papers (33% of the market for this group), sheeting papers, felts (roofing, auto, flooring, etc.) and under board: asbestos and asbestos filled and flexible wood fiber insulation and underboard, insulation boards (fibrous felted for inter-building and wall boards, acoustic tile, etc.) and hard pressed boards (insulating boards with 27% of this market and hard pressed boards with 40%).

Since 1970 production has increased at an average rate of 3.8%. The demand for these grades varies with the housing market.

There is heavy industrial concentration among the producers of insulating and hard boards in which 5 companies control 71% and 62% of the production, respectively.

The capacity estimate for 1978 indicates 2.4 million tons, of which the five majors have 61%.

5.2.4 Recycling

Recycled paper is presently used mainly in the production of recycled boxboard and paperboard (1977 production: about 7.5 million tons), corrugating medium (1977 production: about 4.2 million tons, containing about 20% recycle. A quarter of the cellulose in tissue, a small porportion of newsprint consumed, and a tiny amount of writing paper comes from recycle.[5]

In 1977 the U.S. recycle rate was 21.5%. This rate is brought into a world-wide context in Table 5.2.4A, which compares the foreign trade surpluses and apparent consumptions of paper and board as well as pulp, and shows the waste paper recovery rate for selected countries. Countries with a high waste paper recovery rate such as Austria, the Germanies (DDR and FRG), France, Japan, the Netherlands, and the UK have generally a narrow raw material base and are traditionally good housekeepers; others, such as Mexico, Spain and Italy, have a poor resource base and cheap labor, while Finland and Sweden are greatly aware of the importance of wood and paper to their economy, and treat this material with consideration.

At the other end of the spectrum are Canada, Norway, the U.S.A. and the U.S.S.R., all countries rich in forests and gifted with either poor housekeeping or high labor costs, or both. (It is significant that just a few years ago Sweden and Finland had very much lower recycling rates. Since then their governments have taken action to improve the paper-wood economics. Canada does not even indicate any use of waste paper.)

However, the reasons given for the difference in recycling are by no means conclusive. The rate is greatly variable and subject to the action of economic forces and government manipulation. Before World War II and during the 1940's, the recycle rate in the United States was also in the

Table 5.2.4A: Apparent Consumption and Foreign Trade in Paper and Paperboard, and Pulp, and the Waste Paper Recycling Rate in Selected Countries in 1977.

Country	Apparent Consumption: Paper & Board (Million m. tons)	Apparent Consumption: Pulp (Million m. tons)	Import/(Export) Surplus: Paper & Board (Million m. tons)	Import/(Export) Surplus: Pulp (Million m. tons)	Waste Paper Recovery Rate, %
Australia	1.7	.87	.51	.28	27
Austria	.7	1.11	(.68)	-	61
Brazil	2.5	1.6	.24	-	30
Canada	4.5	12.1	(8.22)	(6.0)	
CSR	1.2	.94	-	.08	26
DDR	1.3	.79	.15	.18	38
FRG	8.4	3.7	1.83	1.8	33
Finland	.60	4.1	(4.02)	(1.2)	27
France	5.6	3.1	.88	1.1	30
Italy	4.2	2.1	-	1.1	46
Japan	15.3	10.1	(.37)	1.0	43
Mexico	1.45	.89	-	.1	55
Netherlands	1.96	.75	.33	.57	45
Norway	.55	1.1	(.68)	(.37)	15
Poland	1.54	1.0	.17	.18	30
South Africa	.99	.70	-	(.18)	27
Spain	2.11	1.4	.14	.13	43
Sweden	1.61	4.3	(3.56)	(3.30)	30
UK	6.91	2.3	2.83	2.0	41
USA	59.05	46.3	3.94	1.1	21.5
USSR	9.58	8.8	(.42)	(.35)	19
Determination	A	B	C	C	D

A = Calculated by per capita consumption x population
B = Pulp Production + Imports - Exports
C = Imports - Exports; Export Surplus is shown in ( )
D = Wastepaper used / Apparent Consumption of paper and board

Source: Pulp and Paper, June 1978

30% to 40% range.

There is in theory no reason why paper cannot be recycled indefinitely. Used paper is just as capable of being reduced to its cellulosic constituent as is the original material. However, recycled waste paper is repulped by agitation in hot water with chemicals that assist in the dispersion of the fibers. To remove the ink from the paper, the pulp is treated subsequently and sometimes subjected to bleaching agents to improve its whiteness.

There is obviously a limit of recyclings to which the cellulose can be subjected. The fibers ultimately become too short to be strong enough (but would then probably be still suitable for specific applications); however considerable quantities of short fibers ultimately are lost in water discharges. Under present operating procedures, certain mixes between pulp and recycle are established for different applications.

De-inked recycled pulp can be used in most applications, but there are distinct limits in each case, inherent in the product and dependent on the techniques and operating procedures of the mill.

Waste paper is graded by the dealer on the basis of origin and intended use: there are four major classes and a large number of subclasses to identify its suitability for one of the many paper or paperboard products.

Just over one ton of combined pulp and recycle is needed to produce a ton of paper. Historically in the U.S. the consumption of wood pulp has been encroaching upon waste paper. Whereas during the 1940's waste contributed about .35 tons to a ton of paper products, it supplies around .2 tons at present.[6]

Table 5.2.4B shows the consumption history of paper, pulp and recycle for the United States since 1950. Paper consumption has more than doubled and that of wood pulp almost tripled between 1950 and the mid-1970's, but waste paper consumption has increased merely by a factor of 1.6 (other fibers refers to rags.) This is reflected in the share of recycling in paper production which declined from 28% in 1950 to a rather consistent level of 20% during the past ten years.

The performance of the industry in 1973/74 as shown in the table is interesting: paper mills were operating at full capacity and there was an apparent shortage in the supply of pulp, with the result that the demand for and supply of waste paper increased by nearly 10% in volume between 1972 and 1973; this is reflected in the price history, given below, although it does not show clearly in the recycle rate. In this period the secondary material was used to expand production of the paper industry.

Table 5.2.4B: U.S. consumption of Paper and its Raw Materials (million tons)

	Total Paper[a] (1)	Pulp[b] (2)	Waste Paper[b] (3)	Other[b] (4)	(3) as % of (1) (5)
1950	29.0	16.5	8.0	1.4	28
1955	34.7	21.5	9.0	1.3	26
1960	39.1	25.7	9.0	1.0	23
1965	49.1	34.0	10.2	.9	21
1970	57.9	43.2	11.8	.8	20
1972	64.4	47.3	12.9	.9	20
1973	66.7	48.8	14.1	.8	21
1974	65.5	48.2	14.0	.8	21
1975	56.0	42.4	11.7	.6	21
1976	57.9	45.4	12.4	.2	21
1977	59.0	46.3	12.7	?	21.5

[a] Apparent

[b] Actual (figures differ slightly from those in Table 5.2.2A, which report production)

Sources: Department of Commerce, Current Industrial Reports, Pulp, Paper and Board, Annual Reports.

Waste Paper 1969: Institute of Paper Chemistry

Waste Paper 1970-77: American Paper Institute

Data in Table 5.2.4C show an approximate one-year lag between the rise of prices for the (selected, typical) wood and that of paper, the

Table 5.2.4C: Price History of Paper, Waste Paper and Wood, 1960-1975; 1976 = 100

Year	Paper	Waste Paper	Wood
1950	68	165	62
1955	83	153	75
1960	93	116	85
1965	95	127	92
1966	98	134	89
1967	100	100	100
1968	102	130	103
1969	106	139	108
1970	111	125	109
1971	114	112	110
1972	116	134	119
1973	121	197	146
1974	149	226	170
1975	173	110	
1976*	182	185	
1977*	194	187	
Sources	(a)	(b)	(c)

Sources:

(a) Paper: Bureau of Labor Statistics, Wholesale Prices & Price Indexes (Code 09-13: Paper)
Definition: Paper = Newsprint, Coated Printing, Book Paper, Bond, Uncoated Index, Wrapping, Shipping Sack, Unbleached Kraft, Butcher's Paper, Waxing Paper, Grocery Sack

(b) Bureau of Labor Statistics, Wholesale Price Index (Code 09-12: Wastepaper)

(c) Wood: Misc. Publ'n No. 1315, USDA Forest Service. Southeastern Pine selected as representative.

*From: American Paper Institute Monthly Statistical Summary, August 1978.

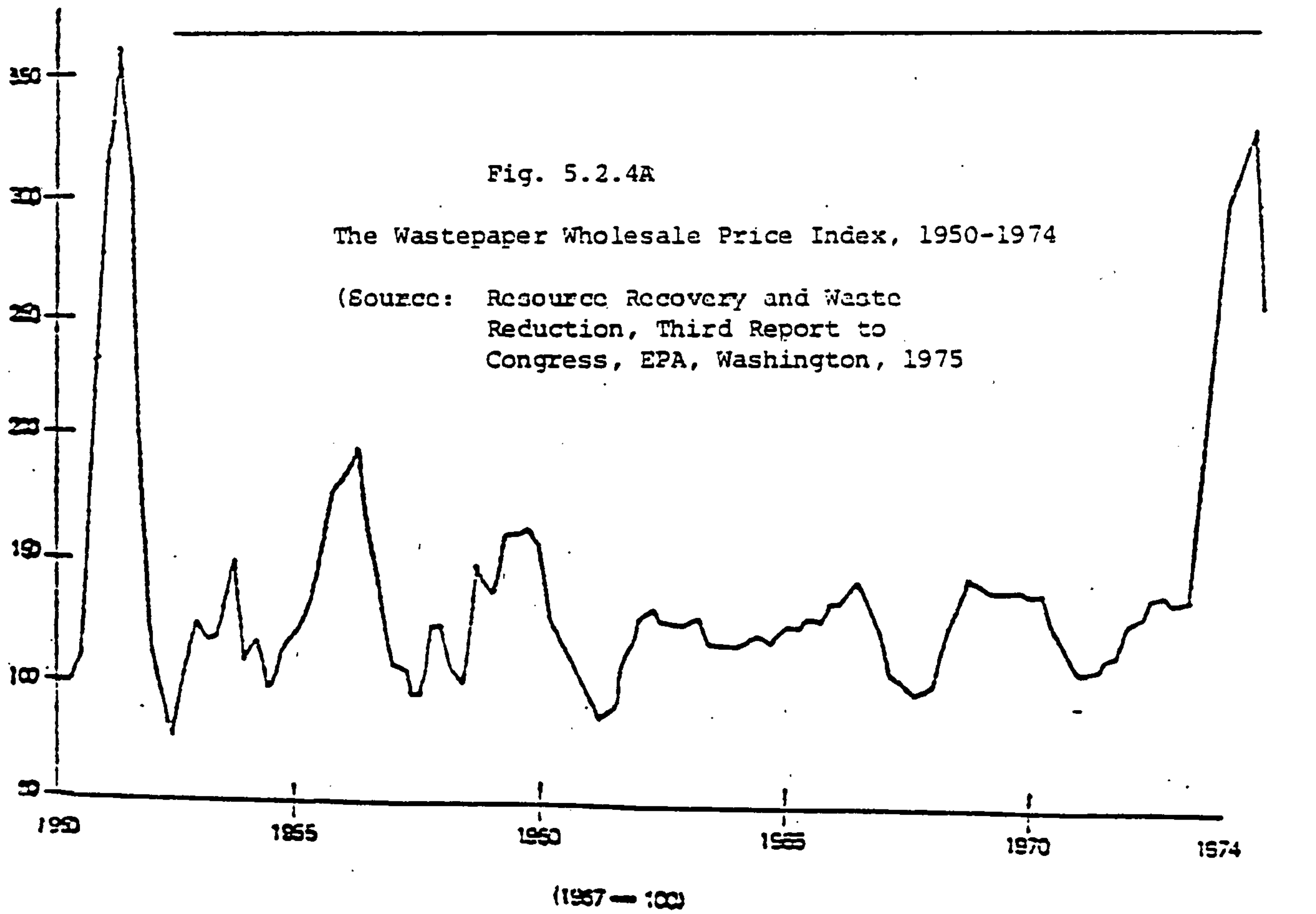


Fig. 5.2.4A

The Wastepaper Wholesale Price Index, 1950-1974

(Source: Resource Recovery and Waste Reduction, Third Report to Congress, EPA, Washington, 1975 price development for waste paper is different. It is related to fluctuations in the demand for paper, and is apparent in Figure 5.2.4D, which shows price developments from 1950 to 1974. Prices jumped in 1973-74 and in 1951 under the impact of the Korean War.

The life cycle of paper is generally less than one year. Therefore, subtracting the recycle from consumption with an allowance of 15% (for long-lived products) will provide an approximate indication of the discard which enters the waste stream. For example, EPA shows residential and commercial postconsumer waste of paper to be 44.2 million tons for 1973. Total paper consumption for that year was 67 million tons. Subtracting 15% from this figure leaves 57 million tons. When the 14 million tons of recycled waste paper are subtracted, the estimate of 43 million tons of unrecovered discard checks quite well against the EPA figure.

What happens to the discard?

In line with its increased use, the amount of paper entering the solid waste stream has increased through the years. Some grades of paper are recycled more than others. The most desirable form of scrap paper is the prompt industrial waste that occurs in the processing of paper products. As the market for these products has grown, so has the volume of the recycle, even though proportionately there has been no improvement in the recycle rate. However, there are indications that attitudes are changing: high-grade paper waste is now being collected in office buildings through source separation programs.

The EPA and other agencies are attempting to expand recycling. An interesting breakdown of the potential in this area has been offered for the year 1973 by EPA[7] as follows:

Type of Wastepaper	Actual Recycle	Disposal Total	Disposal Urban Areas	Potential Recovery Percent	Potential Recovery Million tons
	(million tons)				
Newsprint	2.6	8.0	6.2	55 - 65	3.4 - 4.0
Corrugated	5.3	11.8	9.2	55 - 65	5.1 - 6.0
Printing/writing	3.2	9.7	7.6	30 - 40	2.3 - 3.0
Packaging, etc.	3.4	14.7	11.5	5 - 10	.6 - 1.2
	14.4	44.2	34.5		11.4 14.2

The above tabulation shows, first, the actual recycling for 1973 is 14.4 million tons. It may be noted that from an aggregate consumption of about 10 million tons of newsprint only 2.6 million tons were recycled, (in a year of a high utilization of waste paper). The following columns indicate the disposal problem faced by U.S. municipalities: 44 million tons of paper products were discarded in the refuse, of which EPA estimates 34.5 million tons to be "reachable" because the discard occurred in urban areas.

An arbitrary assumption (or an educated guess) is then made to estimate how much from this urban material might potentially be recovered, and the resultant figure indicates a potential doubling of the recycle rate to about 40%. This greater recovery would then be accompanied by a corresponding decline in the demand for virgin fiber.

What are the impediments in the way of realization of such an objective, which appears desirable on ecological and social grounds, as well as from the point of view of fuel economy?

The present organization for collecting waste paper seems inefficient; it will have to be improved in order to expand recovery. Source separation has the potential for greatly increasing recovery rates.

The secondary paper industry consists of "scavengers" who collect secondary materials and sell to dealers who sort and bale the material before shipping it to the mills.

In 1970 there were some 1,300 waste paper dealers in the United States. The largest of them have either close connections with, or are owned by, paper companies, but the vast majority are small businessmen. For a number of years the dealers payed in the $4 to $10 per ton range (for low-grade stock), and it was not sufficient to bring out much material, since the cost of the pickup was greater than the offered price.

The price is influenced largely by the demand for paperboard (the largest market for waste paper), which is highly responsive to changes in the economy. Consequently the ups and downs of this product are reflected and considerably accentuated in the demand for recycled paper. As a result waste paper collectors and dealers are exposed to the economic swings and must guard themselves by paying a minimum price.

Collections can perhaps be improved by expanding the more stable markets (such as newsprint), by providing a backup use for waste paper as fuel, and by enlisting the efforts of the municipalities to a greater extent, especially with regard to "source separation."

On the demand side, relatively few paper mills are predicated on the use of recycled paper, the "dedicated" mills. Most of the plants are "supplemental use" mills, and waste paper represents only a small fraction of the materials input. Also, the largest producers are integrated into pulp production, a capital-intensive operation, and management must and will keep these facilities operating, to the detriment of using recycle.

The composition of the feed rests to some extent on technical considerations. Only in banner years, such as 1973-74, does recycle encroach upon the use of virgin material (when pulp capacity falls short of requirements), showing that more waste paper could be absorbed by the industry. This fact is also indicated by the feedstock mix of other industrial countries, which consume a range of paper products similar to that marketed in the United States.

One large user[8] believes that the minimum "door price" (i.e. at the dealer's yard) should be $ 20 per ton, and he tries to maintain that level by paying accordingly for the delivered material. The delivered cost of recycle is $ 40 to $ 60 per ton, depending on location.

It is also suggested that, given the energy crisis, the heat value be used to provide a floor under the price of waste paper. At 12 million BTU per ton, a price of $ 18 would furnish a base which would (1) make collection (after source separation) and processing worth while for municipalities and/or waste processors; (2) enable utilities to provide for the necessary equipment to prepare paper for efficient use under boilers; and (3) allow the paper industry to accept properly prepared material by providing the dealer with the targeted "door price."

In the last few years the export market has emerged as a new factor in the determination of the sales price of recycled newspapers. Only about 5% of the total are involved, but the foreign buyer sets a floor price, at least at major shipping points. This disturbs some domestic processors, who prefer stable, long-term price commitments in buying raw material.

Newsprint made from recycled paper is offered in the market at a discount of $ 10 below the official price. Its acceptability is attested by the fact that producing mills are always operating at capacity even though on occasion price concessions bring the cost of newsprint from pulp well below the discount price.

The economics, then, would seem to favor the secondary raw material, but the industry will not be at the mercy of the secondary industry (like the steel makers, it will not idle its "blast furnaces" unless absolutely necessary).

On the other hand, the municipalities carry a much heavier burden, for they have to pay for the disposal of mountains of paper. EPA shows[7] that paper represents just under 40% of the municipal solid waste (m.s.w.) generation. It now costs $ 25 to $ 30 per ton to collect and to dispose of this refuse. The share in this disposal that can accordingly be allocated to paper is $ 11 per ton of m.s.w. The potentially recyclable portion is 40% to 50% of the total paper. It therefore costs $5 per ton of m.s.w. to dispose of the recoverable paper, i.e. it has that much of a negative value.

Two approaches to utilization have been established: burning all refuse--including the potentially recoverable paper--and recycling. The price of paper and paperboard, waste paper, and energy are variables, and a relationship between these factors can be established to determine the economics.[10]

The base is provided by the heat value of paper which is 12 million BTU per ton. Production of newsprint from virgin material requires 24 million BTU per ton, net, while according to actual energy consumption data, production of newsprint from 100% recycle requires 13.5 million BTU per ton, i.e. an energy saving of 10 million BTU without loss of energy content.

Recycling, while extending the service provided by the material, postpones its use as a fuel. It is therefore uneconomic to burn paper, if it can be sold for more than about $ 18 per ton (at present $ 2 is a typical price for 1 million BTU--$ 48 per ton of 24 million BTU coal--depending on location), making allowance for difficulties in and costs associated with plant modifications for burning paper.

Therefore a "door price" at the yard of $ 20 would provide the proper margin to attract waste product into the recycle stream rather than into disposal by burning without preparation.

The only reason why anyone would consider using waste paper as fuel is its negative value as unsegregated municipal solid waste. However, segregation of usable paper is quite a simple matter at the source, and a suitable subject for government action. Both encouragement of paper segregation at the source and discouragement of use of the primary raw material can be effectively undertaken by the agencies of government.

It is also a matter for government action to induce public utilities to use the cheap BTUs provided by paper, even though such economies must be reflected in the billing to customers. (It is alleged that this feature inhibits the use of waste paper by the power industry more than do engineering considerations.)

Like the steel industry, which enjoys the depletion allowance for its iron ore and coal raw materials, the paper industry has the capital gains treatment for timber to favor the primary supply stream. In reviewing the industry structure, we have shown the vast timber holdings of the forest products companies in the U.S. and Canada, and the considerable influence that tax allowances have had on the structure of the timber and thereby the pulp and paper industry.

As shown above in Section 5.2, there is a tendency for paper companies to integrate backwards to the source of virgin raw material, and conversely for timber companies to go forward into paper. About one-third of the paper companies with major timber holdings were originally lumber operations.

The U.S. Treasury, in a study[11] prepared for Congress, points out that:

> In 1965 there were 13,251 corporate returns filed in the lumber and paper industries. Of these, the 16 corporations with assets over $250 million reported 64.8 percent of the long-term capital gains. The 63 corporations with assets over $50 million reported 80.4 percent of the long-term capital gains. In fact, five companies reported 51.3 percent of the long-term capital gains.

Although wood is a renewable resource, current rates of cutting are approaching levels of sustained yield, and better economies in the use of wood products are desirable. Better public relations, publicity, and education aiming at public awareness of the need for conservation and recycling are needed.

On the recycling side of the issue, the Swedish example may be cited: there the exploitation of timber resources has also been excessive, and the recycling of paper has been poor. The Swedish Government has now given municipalities five years to organize the recycling of all available fiber.

In line with the Treasury findings it would seem that public interest requires action by the U.S. Government to discourage the use of primary raw material, and one of the means for accomplishing this might be the repeal of capital gains treatment for the use of wood in paper production.

Stimulating the most constructive use of waste paper is another area for Government action: here it can lend its authority to promote recycling, to support municipalities in their efforts to require segregation of the useful waste at the source.

It is not in the American tradition to adopt mandatory measures such as those undertaken in Sweden, but we can examine how this country achieved much better paper utilization 30 or 40 years ago, and endeavor to reestablish the industry pattern that operated then. We can also, recognizing the new resource ethic, develop new patterns of social action and husband our resources for better materials and energy utilization.

5.3 Process Description--Stages from Wood to Pulp to Paper

The paper making process consists of three stages:

(1) The harvesting of wood or other cellulose source;

(2) The conversion of wood to pulp;

(3) The processing of pulp into paper.

The cell wall of all plants contains cellulose. It is a fibrous material which the chemist calls linear polysaccharide. The cellulose is held together by lignin, and there are other compounds present in the wood in varying amounts. In perennial plants cellulose represents one-half of the structure, but is only one-third in annuals. It is highly hygroscopic, absorbing water, but possesses high strength at the same time as well as great stability.

While paper can probably be made from almost any plant, the non-fibrous constituents impair the suitability in many cases. Trees are outstanding in that they contain a minimum of non-cellulosic constituents. They are classified in a first order into softwoods (coniferous) and hardwoods (deciduous). Softwoods' fibers of cellulose are about one-eighth inch in length, while hardwoods' cellulose fibers are only about one-third as long. The development of the pulp-making process during this century has expanded the range of woods that can be used, and now softwoods are used in papermaking to supply strength, hardwoods, smoothness of surface and body.

For paper of maximum strength, smoothness, body and permanence, fibers of cotton and linen (wastes from textile mills and factories or rags), flax or linters (from processing of cotton seed) are used. The reason for the better properties is seen in the greater length of textile-derived fibers.

Actually, only a small portion of the tree is used for pulp production: the biomass of the tree is as follows:

Roots	12%	±2%	excluded
Branches	9	±3	10
Foliage	7	±2	8
Stump	7	±3	8
Tops	5	±1	6
Trunk	60	±5	68
(bark on trunk	7	±1)	

The above tabulation shows the tree both with root and without, giving the relative importance of the different parts.

The scale of values for wood and wood products is: lumber (highest value), pulp, and fuel. (The economics for the use of wood as a chemical feedstock in the displacement of oil or coal-byproducts are poor. Even wood-derived sugars are prohibitively expensive.)

As a result timber, lumber, pulp and paper operations are increasingly coordinated, and vertical integration of these industries permits optimization of the timber resource. The sawmill produces cut lumber from the core of the tree trunk, while the sawdust and leavings are pulped. Under a more recent development, under whole-tree harvesting, the tree tops, branches, foliage and branches are chipped at the site and can be burned to supply supplemental power and steam for the pulp mill. In some cases different types of pulp are produced in one facility, and the power plant can supply the bulk of the energy needs for the entire operation.

Pulp is produced from wood by mechanical or chemical means. Mechanical pulping abrades the wood to pulp. This can be done by pressing the wood against a grinding wheel or shredding wood chips. In this process the binder, lignin, is broken, and the cellulose is obtained by comminution.

Chemical wood pulp is made by cooking wood chips in a digestor under pressure, either with sulfite salts and SO_2 or in caustic soda and sodium sulfide (the kraft process). Lignin is dissolved by the reagents, and the cellulose is set free as whole fibers. Further purification is achieved by bleaching (and almost one-half of kraft pulp is so treated). The highest grade cellulose, prepared by bleaching and alkaline extraction, is called alpha or chemical pulp (and represents generally around 2% of total kraft production). It goes into rayon or cellulose film or chemicals, such as cellulose nitrate or acetate.

Semi-chemical pulp is made by partly dissolving the lignin, softening the wood chips and mechanically producing the fibers. The pulp is then shipped to the paper mills. If the pulp must move over any considerable distance, it is dried and shipped in bales. (It is then reconstituted in a pulper.) In either case, the cellulose must be prepared for conversion to paper, depending on the product and grade to be made. This is achieved by mechanical pounding of the fiber, and the greater the degree of mechanical action, the greater the strength of the paper and the lower the porosity. During this step, sizing, fillers, dyes, bonding agents, can also be added or the stock can be continuously washed. After proper preparation, the pulp is suspended in water in which it represents only one-half per cent, and is then fed to the paper machine. There are essentially two types of paper machines: the Foudrinier, and the drum type.

The Foudrinier machine receives the slurried pulp from a "head box" on a travelling wire mesh which drains off one-fifth of the water. The drum type consists of a cylinder which is covered with a screen and dips into the pulp slurry. In either case, as the screen moves the density of the slurry increases, and when it reaches between 10% and 25% solids, it can be removed. The wet mass is further consolidated by pressing and drying on drums until the water content reaches 65% to 70%. In a final finishing step, the sheet can be "calendered" by being passed through a stack of rolls which polish the surface of the paper.

It will be seen that this process is quite energy intensive, requiring considerable inputs of electric as well as thermal energy to break down the wood to fiber, to prepare the fiber in a water suspension, to carry the felted material through progressive drying stages through the paper machine, and to supply the heat needed for drying the wet pulp to produce a paper.

Figure 5.1.A, Basic Papermaking Operations (page 3) shows the schematic of the papermaking process. Subsequent sections of this chapter describe the process in greater detail and develop the energy requirements for each step. Overall electric and thermal energy requirements have been discussed above in Section 5.2.1.

The environmental impact of pulp and paper mills was reported by Kaplan.[28] He indicates that conventional waste treatment techniques are employed to correct fluid effluents for dissolved and suspended matter, cooling ponds or towers for heat dissipation.

The energy consumed in controlling discharges into the atmosphere goes into electrostatic precipitators and small gas scrubbers. Present standards require about .25 to 1 million BTU per ton of product. These energy expenditures are of course contained in the data presented above and below. However, proposed tightening of standards may raise these energy expenditures by a factor of 2 to 2.5. Similarly, liquid discharge controls will impose a need for an incremental 100,000 to 300,000 BTU per ton.

5.3.1 Pulp Production

As outlined above, there are three basic methods for producing pulp from wood for the manufacture of paper and pulp.

However, before the wood can be treated to produce fiber, it has to be collected as timber and shipped to the pulp mill.

The energy required to fell and load a cord of roundwood has been estimated both in the U.S. and Canada,[12] and in both it can be shown that requirements in gasoline for

felling are	.7 gals;
skidding are	1.2 gals;
loading are	.6 gals;
	2.5 gals/cord;
	1.25 gals/green ton.

Therefore the harvesting expenditures of energy are about 200,000 BTU per ton of roundwood as cut.

Yield from roundwood from standing timber is reported to be in the order of 60%. The balance is wood in the form of branches and tree tops, disregarding the root system. In the past this material was either left on the cut-over site or it was gathered after drying and burned under supervision to prevent a fire from spreading.

There is now an increasing trend to utilize the whole tree (in some instances including the roots). This is accomplished by chipping the waste material on the site and shipping it to the mill to be used as fuel or--under some practices--feeding it to the pulp mill. However, after some initial success, this approach is now being reconsidered because of difficulties arising from corrosion problems in the pulp mill. It seems that dirt and dust adhering to the feed causes complex side reactions in the digestion process and subsequent operations.

Considerable work is being done to cope with this problem and ultimately this "total chipping" may be adopted in pulping operations. Some promising results have been obtained in a process developed by the Pulp and Paper Research Institute of Canada, which involves aging and wetting the chips, followed by agitation in water and screening out dirt, foliage and bark. It is claimed that a clean feed to the pulp mill and a separate stream has been provided which can be used as fuel.

Based on a Canadian survey conducted by Middleton Associates[12] roundwood or wood residues travel an average of 50 miles to a pulp mill. These data are considered to be also valid for U.S. operations. Most frequently such a movement is effected by truck. In arriving at total energy associated with a ton-mile travel, Middleton assumes a factor of 1.4 to arrive at an assessment of the BTU content in equipment, service and maintenance above the consumption of fuel, as follows:

Energy Cost for Transportation, BTU / ton-mile

	Direct	Total/Direct	Total
Truck	2,500	1.4	3,500
Rail	560	1.7	950

These figures are national averages, taking into account factors such as incomplete loading, empty back haul, etc. Conversely, they do not allow for the special heavy duty trucks or difficult lumbering roads associated with the lumber industry.

Allowing for an average trip of 50 miles, then the total energy required to get a ton of wood to a pulp mill is in the order of 175,000 BTU.

Accordingly, the ton of green roundwood delivered to the pulp mill carries an energy investment of about 375,000 BTU.

The roundwood arrives at the mill in full-length logs or as bolts, about four feet long, to be charged directly into large, revolving drums in which the bark (amounting to 12-15% of the feed) is removed by tumbling action.

Barking drums are standard 22 ft. 6 in. long by 12 ft. diameter (but larger units are also in service). They can process 10 cords of softwood or 5 - 7 1/2 cords of hardwood per hour (or 20-25, and 10-19 tons, respectively). These drums can be placed end-to-end up to three units, to increase output. The bark goes to boilers as fuel, and the debarked logs are sent on to chipmaking or groundwood machines.

Power consumption by barking drums is 13.5 kwh / ton of green roundwood as given by Middleton;[12] Gordian[13] gives 16.2 kwh / ton for friction drum barking, 25 kwh / ton for hydraulic barking.

5.3.1.1 <u>Mechanical Pulp Production</u>

As the term implies, mechanical pulp production is the physical comminution of wood to pulp.

There are two methods: either grinding the debarked roundwood against a stone grinding wheel (stone roundwood), or chipping it first and then feeding the chips into a "refiner" in which they are turned into a pulp ("refiner groundwood" is considered superior to the stone-ground grade). The moisture content is important, both for grinding and product quality. It should be at least 30%, but preferably close to 50%, and may require pretreatment of the wood. Stone grinding wheels are made from silicon carbide or alumina grains (of controlled size) in a binder matrix. The "stone" is connected to an electric motor, often rated at as much as 10,000 hp. The pulpstone turns at 360 rpm, i.e. peripheral speeds of between 4,000 and 4,500 feet per minute. The wood is pressed against the stone either by weight or by a hydraulic pressure foot, and each stone produces as much as 150 tons of pulp per day. Yield from wood to fiber is very high (94%-96%), as the lignin is not removed in the attritioning process.

Refiner pulpwood is first chipped to about one by one-half by one-fourth inch against a flywheel with cutter bars. Large chippers with a capacity of 110 to 180 tons per hour require multiple drives with 750 to 2000 KW. Power consumption is about 100 kwh / ton of chips. Chips are then fed to "refiners," consisting of two discs, having alternate ridges and depressions on facing surfaces. Clearance between them is adjustable, as they rotate opposite each other and grind up the wood chips. Several of these units are working together to process the pulp in stages leading up to a screen, with the oversize being recycled for reprocessing. (There are a number of designs of refiners, some of which have only one disc.) Rotation is much faster than in stone wheel pulping, reaching 12,000-30,000 feet of peripheral travel per minute.

Overall yield from debarked wood is high and ranges between 94% and 96%, and also power consumption, which is 1,527 kwh per air dried ton (ADT) or 1,967 kwh per bone dry ton of pulp produced.[14] (This report assumes that this figure is meant to be comprehensive, and that it includes the energy expended in chipping as well as that required for refining. It is however found that power requirements vary widely, depending on the type of wood processed and on possible pre-treatment, such as soaking, "pressafining" or "impressafining.") In terms of thermal values this power requirement represents 16 million BTU. This compares with figures given by EPA[15] of 15.1 M BTU/ADT for refiner mechanical and 13.3 million BTU/ADT of groundwood pulp.

Other investigators give a range of 10 to 17 million BTU per ton of "groundwood pulping"[16] without defining the parameters surrounding this wide range. Again, Battelle[17] gives a power consumption of 11.4 million BTU per ton of pulp.

It has been pointed out that there is a wide range of parameter surrounding power consumption in the manufacture of mechanical pulp. Since the present study aims at order-of-magnitude determinations, it may be appropriate simply to average the figures quoted above and to assume a power consumption of 14 million BTU per ton of air dried wood pulp. It is to be understood that the entire energy is required as mechanical or electrical energy, i.e. 1,400 kwh.

5.3.1.2 Soda or Sulfate Process

Soda pulp (by the original chemical pulping process) is obtained by cooking wood chips with two-thirds caustic soda and one-third sodium sulfide at an elevated temperature under pressure. A reaction between the reagents and lignin converts the wood into separate fibers. (The kraft process evolved from this chemistry and has superseded it almost entirely.) The process is now limited to the production of filler pulps from hardwood, as the material is relatively low in strength.[18]

After completion of the operation, the cellulose produced is washed to remove remaining impurities, and then bleached. Soda is largely recovered and recycled.

The significance of the process has declined, owing to the poor quality of the product (it is included under "other" in Table 5.2.2A, "U.S. Production of Pulp"). Only two very old mills continue to use this obsolete technology in the U.S.

5.3.1.3 Sulfite Pulping

The sulfite pulping process accounts for 7% to 8% of total U.S. pulp production (see Table 5.2.2A), more in former years.

Sulfite cooking liquor contains 4% to 8% free SO_2 as well as 2% to 3% Na, Ca, Mg, or NH_4 bisulfite in an aqueous solution. This liquor is pumped into a pressure vessel which is loaded with wood chips. The reactor is commonly about 16 feet in diameter, 50 feet high, and has a capacity of 12 to 15 tons of pulp per batch, but much larger units have been used.

Sulfite pulping practice greatly varies, depending on the chemistry and design employed in any given plant. There are many variations of the process used in the 41 sulfite mills that are now in use in the U.S.--a considerable decline from the 96 plants operating in 1920.[29] There is no new technology in view that might revive the process, and no new sulfite mills are being built or considered. It is difficult to generalize about the power requirements in these mills.

Raw material for sulfite pulping is generally a low-resin conifer, such as spruce. The product is classified into five grades of unbleached sulfite pulp, depending on the degree of cooking, and two major grades of bleached sulfite pulp: bond, for strong, bright papers, and book grade, clean and bright but not as strong.

In processing, wood chips containing 45% to 40% water are charged into the digester to fill it completely; then the hot acid solution is pumped in, and steam heat is provided. At the end of the "cook," the digester discharges rapidly into a "blow pit," and the blow defibers the chips. Unwanted knots, uncooked chips, dirt, bark, fiber bundles, etc., are screened out.

The temperature of the cook is in the order of 150°C, and the time about five hours.

Yield is 44% to 46% typically for wood holding 2% to 5% lignin. The pulp is relatively light in color and can be used without bleaching, particularly when mixed with groundwood pulp. For applications requiring greater whiteness, additional bleaching may be needed.

The process requires more fuel for pulping, less for bleaching than sulfate pulping, and total fuel consumption is 7 to 8 million BTU per ton, including washing, refining and bleaching.[19]

5.3.1.4 Sulfate Pulping--Kraft Process

About two-thirds of the pulp produced in the U.S. is made by the sulfate or kraft process. In this process wood chips are cooked in a liquor of caustic soda, sodium carbonate and sodium sulfide for about 3 hours at 340°F under pressure.

Lignin is solubilized and the cellulose is set free. The cooking liquors are removed and recovered, while the pulp is washed, bleached (if required) and sent to the paper mill. In order to show the complexity of the operations involved, the following describes in some detail the many steps, reactions and circuits needed in this process.

In the sulfate or kraft process, chips are digested in "white liquor," which contains NaOH and Na_2S (the ratio of sodium in these compounds is 2 : 1, respectively). The liquor also contains sodium carbonate and sulfate in significant amounts and minor quantities of others.

The reactivity of the liquor is stated in terms of the Na_2O equivalent, since the Na_2S hydrolyzes, one-half being available as caustic, one-half as hydrosulphide (NaHS), which is the crucial reagent in starting delignification.

Fifteen to sixteen lb. of effective Na_2O are used per 100 lb. of dry weight of spruce, for example. About 3.1 lb. go to delignification, .9 lb. react with the acetic acid formed and 6.8 lb. are consumed by hemicellulose byproducts. Some 4 to 4.5 lb. are left in the spent liquor.

In batch operations, the digester is heated to 170°C (338°F) in one and one-half hours and held at temperature for one and one-half hours. The liquor to wood ratio is 4 : 1, and 16 lb. of effective alkali will produce a bleachable pulp. A valve at the bottom of the tank empties the contents into the "blow tank."

Most modern mills operate continuously, frequently employing the Kamyr digester: chips are first continuously steamed, then brought up to the pressure of the digester (about 150 psi) and then mixed with the white liquor while flowing through the digester for one and one-half hours while heating to 170°C. The mass is held in a second zone for another one and one-half hours at temperature.

Digestion having been completed, chips enter a counter-current washing and cooling zone in the reactor. While the liquor leaves from the top of the zone, digested and washed chips go from the digester through a blow valve into the blow tank.

Fig. 5.3.1.4A shows the schematics of the recovery system: the chemical recovery cycle importantly involves the separation of the black liquor resulting from the reaction with the chips, by washing on rotary filters, its evaporation in two stages, and combustion to recover the inorganic chemicals.

Oxidation of the black liquor is required to prevent escape of deleterious compounds. When concentration of black liquor reaches 65% to 70%, it goes to the recovery furnace.

The recovery furnace is part of a boiler. Combustion of organic matter raises steam (either at 200 psi for process steam only, or at 1200 psi to generate power as well), and the sodium carbonate and sulfide are recovered in the ash, called "smelt," which flows from the hearth into the dissolving tank (at 990°-1200°C). The furnace is of quite an exceptional design (especially, since serious explosions occur if water leaks into the hearth) to insure both maximum thermal and chemical recovery efficiency.

In the dissolving tank "green liquor" is generated, the color being due to an insoluble residue, the "dregs," i.e. minor constituents of wood,

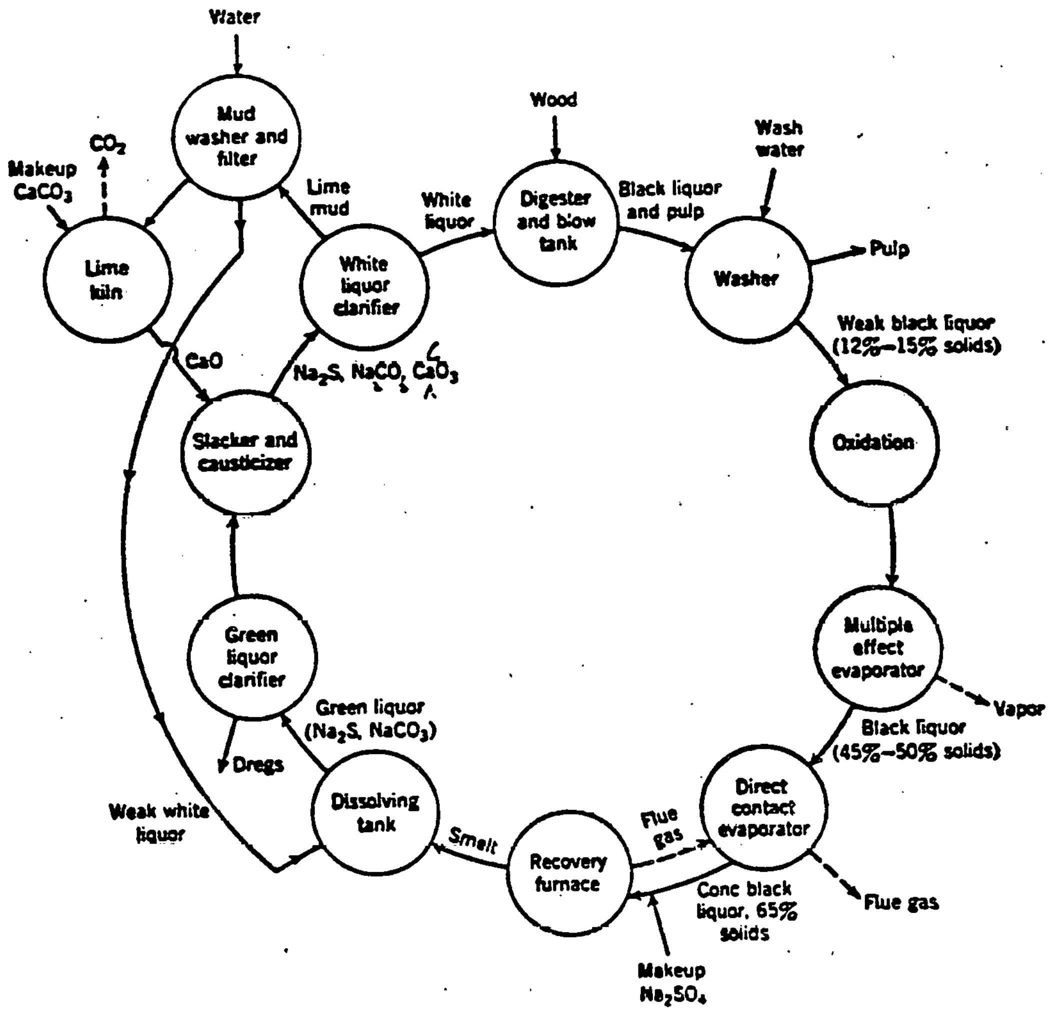


Fig. 5.3.1.4A: The Cyclic Recovery System for the Kraft Process

Source: Encyclopedia of Chemical Technology
"Pulp" p. 708.

water or corrosion products. This liquor is purified by decantation, and "white liquor" is reconstituted for reuse after adjustment of analysis.

Byproducts recovered are turpentine (from digester gases, about 20 lb. per ton of pulp for pine, much less for spruce), tall oil ("salted out" from liquor at 25% to 28% concentration as a soap—it must be treated to recover the oil: yield is 20 lb. per ton and may be as high as 200 lb. per ton from pine. Tall oil is an important raw material for soaps, and for resins used in the sizing of paper), and lignin (can be obtained from black liquor. It can be the feedstock for the production of plastics. Economics are determined by the price of phenol).

The description of the kraft pulping process shows not only the complexity of the process (which has only been barely outlined), but it also indicates that a considerable portion of the thermal and electric power needs of the pulp and paper industry is supplied from in-house generation from byproduct sources.

The yield from debarked roundwood to dried pulp varies with the grade of pulp produced. Pulp for linerboard is relatively low-grade and has a yield of 55-58% pulp vs. feed, while a bleachable pulp has about 46 and high-grade alpha or chemical grade 35-36% yield. It is easy to achieve a high thermal efficiency for a low-yield material, as it generates a large volume of black liquor. A considerable excess of power and steam can be achieved for the better grades. At 50% yield 1 ton of pulp generates 1 ton of waste plus 270 lb. of bark, i.e. a thermal potential of 10 million BTU.

The quantification of the gross and net power requirements is quite complex, and the different studies seem to diverge, because they relate to plants of different efficiencies, they often do not specify the grade of kraft pulp being discussed, and they are sometimes based on different assumptions for power conversion factors which are not always defined.

(Throughout this study, we have tried to use 10,000 BTU per kwh.)

Overall energy requirements are given by Thermo-Electron[20] as 7 to 9 million BTU (net) per ton of sulfate pulp, including washing and refining, plus 3 to 4 million BTU per ton for bleaching.

A much more detailed evaluation by EPA[21] quotes Arthur D. Little as follows (for a ton of bone dry pulp):

	Steam Million BTU	Power Million BTU	Total Million BTU
Wood preparation	---	1.1	1.1
Pulping	4.9	1.2	6.1
Chemical Recovery	4.9	1.5	6.4
Liquor Preparation	.9	.3	1.2
Environmental	---	.7	.7
Miscellaneous	.7	.2	.9
Lime Reburning	---	---	1.4
	11.4	5.0*	17.8
Bleaching	9.1	1.0	10.1
Internal Generation:			
from spent liquor		16.0	
from bark and sawdust		1.0	
		17.0	

* = 500 kwh

The plant efficiency is 95%, i.e. the calculation relates to the most modern plants, of which there are only a very few in the country. However, the thermal requirements for bleaching are shown to equal approximately the sum of sulfate pulping and bleaching thermal requirements as shown by Thermo Electron.

Harris[22] clearly defines his parameters and offers the following data:

Energy Consumption in Kraft Pulping

	Steam & Fuel Million BTU/ADT	Electricity Kwh/ADT
Wood preparation	---	74
Pulping	2.7	52
Washing, screening	---	112
Bleaching	2.3	105
Drying, baling	3.2	145
Recovery boiler	.4	30
Auxiliary boiler	.2	30
Power generation	2.8	15
Recausticizing	2.3	35
Evaporation	3.8	32
Effluent treatment	.3	70
	18.0	700*

* = 450 kwh (without bleaching, drying and baling)

Harris states that combustion of bark and waste fiber account for 9%

of total fuel needs, and black liquor for 63%. According to a telephone interview, Harris used 4,000 BTU/kwh. Accordingly, total thermal requirements are 20.8 million BTU, and 72% of this or 15 million BTU are supplied internally, satisfying first all of the power needs. This leaves only 3 million BTU to be supplied from the outside. However, on the basis of 10,000 BTU/kwh, i.e. the true thermal value of electric power, total energy requirements are 25 million BTU, of which 15 million are supplied internally, leaving a net fuel requirement of 10 million BTU, of which bleaching represents 3.4 and drying, baling 4.7 million. Actual outside fuel requirements are two million BTU and the thermal efficiency for the pulping process is 88%.

According to well informed industry sources, an optimum energy efficiency of kraft pulping of 15-20% is the best operation that has been achieved on a continuous basis. This would appear to support Harris' data. It does however indicate that the present average industry-wide recovery rate of about 50% of energy can well be improved and a further saving of 4 million BTU per ton of kraft pulp should be attainable.

In our calculations we have used a net energy requirement of 8 million BTU per ton of kraft pulp as the U.S. average. Electric power needs of about 500 kwh are included in the overall energy requirements.

5.3.1.5 Other Pulping Processes

The most important among other pulping processes is the production of semi-chemical pulping, which contributes about 8% to U.S. production.

In this process wood chips are cooked with sodium compounds to remove a portion of the lignin. The process applies particularly to hardwoods (which do not produce satisfactory groundwood pulp for paper manufacture). The chemical treatment swells the wood and reduces its tensile strength.

The fibers are preserved thereby and less power is required in the refiner, with consequent lower heat generation and degradation of the fibers. There are a number of forms for practicing the semi-chemical pulping process:

(1) Hardwood neutral sulfite semi-chemical (NSSC), using sodium carbonate and sulfite--produces yields of 70-80% pulp from wood, and is used in corrugating medium. In yields of 60-65% pulp may be bleached for the production of fine papers.

(2) Softwood bisulfite, high yield (60-65%) pulp is used for newsprint and board.

(3) Softwood sulfite high-yield (55%) pulp is used for linerboard.

A range of sodium chemicals is used, similar to chemical pulp manufacture, but reaction is stopped before delignification occurs.

The treated chips are pressed and washed for removal of liquor, and passed on to disc refiners for pulping. The washed pulp is once more refined and cleaned and then goes to papermaking.

Power consumption is somewhat higher in electricity (200 to 500 kwh per ton of fibers), lower in fuel (3 million BTU). Total requirements are 5-8 million BTU per ton, including washing and refining.[23]

In the production of fibers from rags, the raw material is clipped to small pieces and treated with caustic soda in a digester at 23 psig for 3-4 hours. As the cellulose is degraded, the product breaks down in the mechanical action of the beater, which produces the fibrous pulp. After bleaching and washing, the pulp is ready for papermaking.

Cotton linters (short staple cotton remaining after the ginning of cotton seed) is pulped and used as a substitute for regular pulps.

Flax straw, cooked with caustic soda and sodium sulfide, is made into a pulp for the production of cigarette paper, or banknote or other specialty stocks. Many other raw materials have been and are being used, if not in the U.S., then elsewhere in the world.

5.3.2 Paper Production

Pulp goes from the pulp mill to paper mills in the form of a slurry when the mills are nearby, as dry sheets (laps) when such shipment is uneconomic. Dry sheet pulp must be made into a slurry again, "slushed" before use.

All pulps are "beaten" (or "refined") before processing. In this operation the cellulose fibers are swollen, cut, macerated and "fibrillated" --subjected to physical change. An untreated pulp produces a light, fluffy, porous, weak sheet; a well-beaten one, a dense hard and strong paper. The ultimate of pulp refining is the glassine sheet. Refining causes changes in the pulp that increase the ability of the fibers to bond tightly.

Equipment used in this processing step is varied (but is much like that used in the preparation of refined pulp). It is mostly based on the "hollander" or on the "refiner." The hollander is an elongated tub with a central partition. Rolls holding knives circulate in the 'trench' in which is set an opposing group of knives. Clearance between the two controls the severity of the beating. The refiner accomplishes the same effect either in a conical shell, holding knives operating against a rotating plug, or in machines in which spring-loaded discs with ridges are used to work on the pulp.

Properties of the refined cellulose stock are affected by many factors, depending on the tree species, pulping processes, the blend, feed rate, setting, residence, type and condition of machine used.

Pigments and filler are added to the pulp also at this point. They can range between 2% and 40% of the final weight of the product.

Additives include: for filling and coating, kaolin, talc and titania (for fine papers), calcium carbonate (book and cigarette papers), zinc sulfate and lithopone (for resistance to wetting, especially of writing and wrapping papers); size is needed, such as rosin, glue, starch, wax, casein, etc.; for colors other than white, pigments, which are generally introduced in the form of water-soluble synthetic organic dyestuffs.

The cellulose slurry, mixed and ready for papermaking, is called "furnish," and consists of a dilute suspension of fibers and addition agents. It is prepared in the "stock chest" at a consistency of 2% to 4%, and then is cleaned, screened and deaerated. The furnish is then further diluted with recycled "white water" from the paper machine, to hold one-half of a percent of solids (199 lb. of water per lb.).

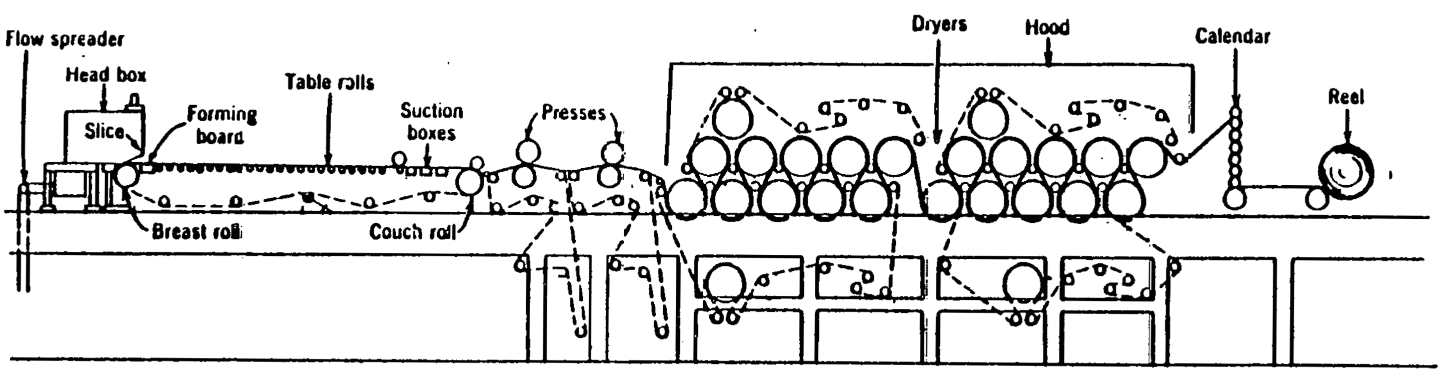
The paper sheet is formed by catching the suspended fibers on a moving fine mesh screen. Enough water is drained from the solids so that a coherent wet sheet can be lifted off the screen at a later point of travel for further drying to paper. Two major types of papermaking machines are in use: the Foudrinier and the cylindrical type.

The Foudrinier machine consists of a long, continuous screen that travels horizontally between two main rolls. The furnish is fed on to it through a flow spreader to provide a uniform constant flow of slurry (99.0%-99.5% water) to cover the full width of the machine. The slurry is discharged into a "headbox" which controls turbulence and provides the proper hydrostatic head to make the slurry flow at a proper rate and pressure through the "slice" onto the moving screen at an appropriate rate (which may in the case of newsprint travel at speeds of up to 5,000 ft. per minute, or about 60 m.p.h.).

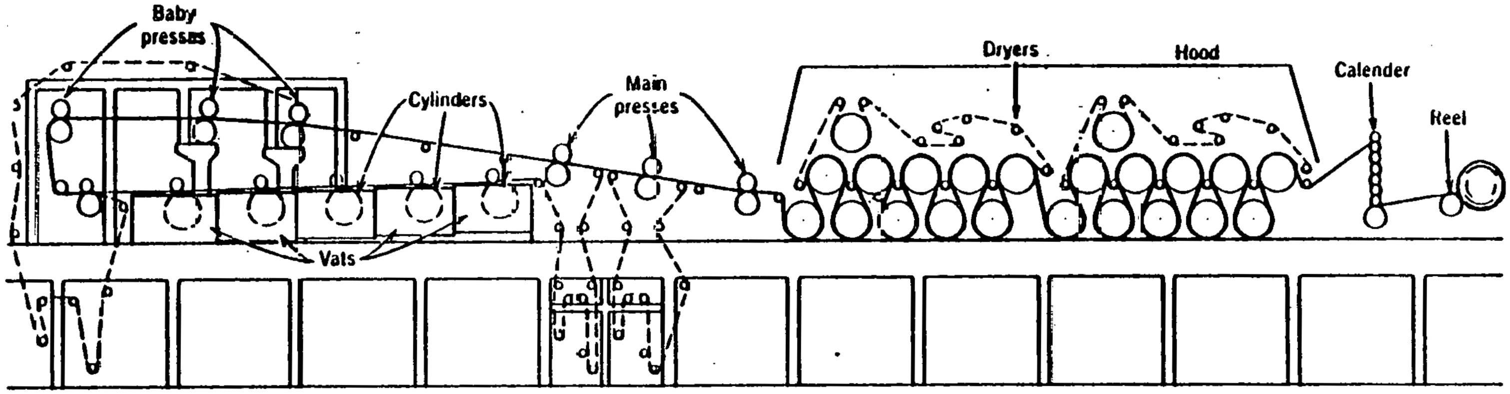
The screen (made of bronze or, nowadays, plastic) moves between two rolls, the breast roll at the head box, and the couch roll at the discharge end. The screen used to be supported by a considerable number of "table rolls" but are now going over "hydrofoils" and polyethylene "suction boxes" and other devices assisting in the formation and drainage of the paper sheet. As the slurry is deposited, water passes through the screen. Although the wet sheet leaving the couch roll still contains over 80% water, it can now be lifted off for further treatment.

Foudrinier machines produce all sorts of paper and board, while cylinder machines are more extensively used in the manufacture of heavy, multi-ply board. See Fig. 5.3.2A.

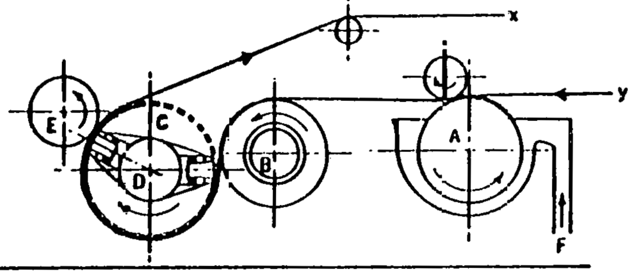
Fig. 5.3.2A



The Fourdrinier paper machine. Courtesy Beloit Corp.



The cylinder paper machine. Courtesy Beloit Corp.



Detail of cylinder paper machine. A, last cylinder, taking up slurry from the surrounding vat; B, extractor; C, perforated cylinder containing D, a stationary water extractor (suction principle); E, press; F, supply of slurry; *x*, paper on its way to the dryers; *y*, multiple wet-paper sheet coming from previous cylinders. From J. F. and C. J. van Oss, *Warenkennis en Technologie*, Vol. V, p. 679. Courtesy J. H. de Bussy, Amsterdam, Netherlands.

Cylinder machines drain the water through a wire mesh drum as it rotates in the slurry. When multiple drums are used, there is a possibility of feeding different furnishes at different stages onto them and combining the strips. Thereby a number of plies with different properties can be combined to produce a multi-ply product. There are many special features modifying the basic designs of these papermaking machines.

At the point where the wet cellulose sheet leaves the machine, the strip passes through presses which remove water by mechanical action, i.e. by pressing the wet sheet. Such presses are like rolling mills with the rolls being either solid or perforated (with internal suction drawing off the water). The sheet is carried between the rolls on felt bands which support it and blot off moisture.

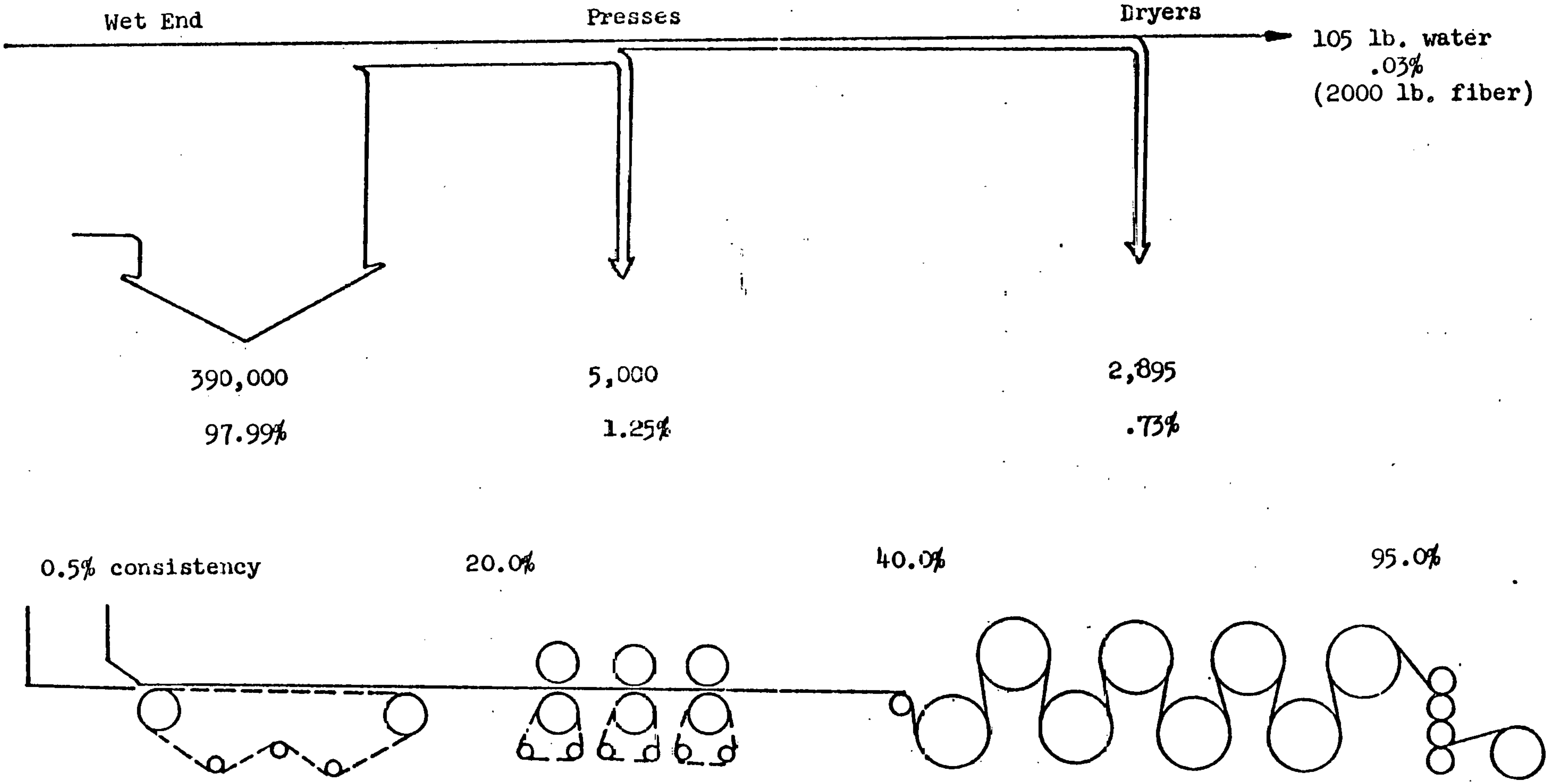
At this stage, the water content is reduced to a level of 65% to 70% (1 lb. of dry substance loses 2.5 lb., as moisture drops from 80% to 60%, or from 5 to 1.5 lb.)--and this is the present limit of mechanical water removal in commercial operations. Fig. 5.3.2B illustrates water removal.

The wet sheet must now be dried by heat (about one-half of the heat required in papermaking is consumed here). Drying is accomplished by passing the mass between a series of steam-heated cylinders which heat alternate sides of the wet sheet, as it passes from one to the other. Again, close contact between rolls and the wet strip is insured by felt bands that carry and smooth it, and improve the physical properties of the final paper. Steam from the paper is captured by a hood that covers the entire drying section, and in some plants, heat is recovered.

Taking into account all the forms in which water is used and recycled in the operation, net consumption is 8,000-10,000 gals (37 tons) per ton of paper.[15]

Fig. 5.3.2B

Source: Institute of Paper Chemistry



Water Removal on Paper Machine

There are many variations in the basic concepts described above, including the use of special drums for the production of creped papers, hot-air and infrared drying.

The process is very efficient and fiber losses are only in the 3% range. The "white water," containing most of the fibers lost in the felt-forming step, is recycled.

The energy requirements of the paper-making process per se are mechanical or electrical and thermal. Energy is needed for stock preparation (beating) and for moving the material from that point at the beginning to the reel at the end of the process, for recycling water from the Foudrinier and the presses, and for moving air and steam above the roll section. Heat is required for evaporating 1.5 lb. of water per lb. of fiber. It is supplied in the form of low-pressure steam.

The mechanical energy in most paper mills is a mix of electrical and steam drives. It is therefore difficult to assign an electrical value to it. It also varies a great deal with the type and grade of product, the size of the operation, the location and design of the mill.

Arthur D. Little[15] gives steam consumption as 10 million BTU and power as 350 kwh per ton of bleached kraft paper and board. Since the heat required for evaporating the water after the press rolls is only in the order of 4 million BTU, the balance of the steam consumed clearly went into mechanical applications in this particular estimate.

It has been suggested in Section 5.2.1 that considerable energy savings could be effected if the paper industry would make use of low-grade steam or other heat now wasted in power stations, chemical or metallurgical plants (or indeed available from geothermal sources); such steam will probably not contain enough residual mechanical energy to drive machinery, but it could certainly supply the thermal energy for drying paper.

In one mill in which such waste steam is used--processing 100% waste paper into newsprint--total power requirements work out as 680 kwh plus purchased steam at 6.7 million BTU per ton of product. This operation offers some indication of actual mechanical energy needs. The incremental steps of handling waste paper, of repulping and de-inking, require probably about 280 kwh and 3.0 million BTU of steam--which are not needed when the raw material is pulp.

Accordingly, the paper-making process (for newsprint) requires 400 kwh of mechanical plus 3.7 million BTU of thermal energy.

Practically all paper is converted by further processing: embossing, impregnating, laminating, coating, etc.

Pigment coatings (kaolin, mica, titania) provide a bright and--as required--glossy or dull, ink-receptive surface. They are applied as extremely fine particles in a water-suspension, followed by drying. In modern plants, at least the initial coating is applied directly, as the paper passes through the paper-making machine.

Adhesives are added to bind pigment particles to each other and to the surface of the paper. Surface properties are greatly affected by the amount and type of adhesives used, and several are often combined to achieve desired characteristics. Among suitable materials are glue, casein, starch, various forms of latex, acrylics, polyvinyls.

Special coatings are frequently needed to establish a barrier against water, vapors, etc. This is achieved by coatings and films, using a wide range of organic and inorganic materials. At various stages in the entire paper-making process other chemicals are needed to modify or control reactions such as foaming, dispersion, microbial action.

Paper surfaces are further improved by calendering or super-calendering by passing paper between rolls under high pressure, thereby burnishing, improving its shine and density.

The production of various grades of paper and paperboard comprises the following rough parameters:

Newsprint and uncoated groundwood: usually more than 50% groundwood pulp in the fiber furnish. These papers are used uncoated and where there is no need for the paper to maintain its color and strength over any length of time. Newsprint is generally 80% unbleached groundwood and 20% semi-bleached kraft or unbleached sulfite pulp. Only three mills in the U.S. make newsprint from 100% recycled paper. Uncoated groundwood paper is based on 30% to 50% bleached chemical and 50% to 70% groundwood pulp. It is used for telephone directories, catalogs, etc.

Average energy requirements[15] in the production of a ton of newsprint and uncoated groundwood are 12.7 and 14.4 million BTU of purchased energy, respectively, for the required pulp and for conversion to product in the paper mill. Total recycled energy is 3.3 million BTU per ton.

Printing, writing, etc., papers are marketed in four grades: coated, uncoated, converting and writing papers. These grades are made from bleached pulp. Coated stock goes into magazines (50-50, groundwood-chemical pulp) and textbooks, brochures (100% chemical pulp). Uncoated paper is made into books, commercial printing stock, envelopes, pads, etc., containing usually a maximum of 25% groundwood. Writing pads include "forms bond" for all business forms. Computer printing is the largest selling grade in this group, making up over 25% of it.

Energy requirements for this group of papers are estimated[15] at an average of 11.3 million BTU contained in the purchased pulp, and 18.1 million BTU in the production of paper on the basis of a ton of product. (Energy recycle in pulpmaking is 12.7 million BTU.)

Tissue is made from a combination of various bleached sulfite and kraft pulps, some groundwood and de-inked or high-grade waste paper. Sanitary tissue accounts for over 90% of the market of this sector.

Net thermal needs per ton of this material are given[15] as, typically, 10 million BTU for the pulp mix used plus 19 million BTU for turning it into product, about 11 million BTU are recovered during pulping.

Packaging and converting papers are in three groups: unbleached kraft for wrapping papers, grocery bags, shipping sacks, etc.

Paper bags can be single, double, or multiwall; they are made on machines from continuous paper strips, bleached or unbleached. The kraft bag is the most usual type. It is made primarily from unbleached kraft pulp.

Multiwall shipping sacks are flexible in mode of construction and highly adaptable to the shipping of a variety of materials. They can absorb energy without rupturing and are made in one to six plies. Impact resistance is better with more layers of lighter paper than with fewer plies of heavier paper, while heavy paper is more resistant to puncturing. Special coatings and plies are needed for special requirements.

Bleached kraft goes into special wrappings, bags, food cartons, including glassine, greaseproof and vegetable parchment to line packages made from bleached or unbleached kraft and sulfide pulps.

Third, other converting paperboard includes a wide array of special industrial papers for such purposes as abrasive papers, insulation, cables; within this group tube, can and drum paperboard, wound from two or more plies of board glued together, is made from paper waste in any number of shapes and sizes.[15]

Average U.S. net BTU requirements are given for this sector as 5.6 million for the pulp and 17.8 million for papermaking, with 13.2 million BTU being recovered in pulp production. Gross thermal requirements are 36.6 million BTU per ton of product.

Containers are made from paperboard or a combination of paperboard and paper, and the furnish is either unbleached kraft pulp or waste paper or a blend of the two.

Set-up boxes must have good stiffness and looks for shoe or candy boxes, etc. They are made from single ply, non-bending paperboard. Folding cartons are filled or solid boxboard, and are made from either (1) bleached paperboard or solid bleached sulfate board (from bleached sulfate or kraft pulps, coated with clay or polyethylene) or (2) recycled paperboard (usually from prompt industrial recycle). Bleached bristol (for cards, file-folders, etc.) is similar to bleached paperboard, but usually has some waste paper admixture.

Solid fiber boxes are made from built-up (combined) container board. Corrugated boxes have a cell structure between facings of high-strength container board and combine high compressive strength with low weight. They are made from unbleached kraft or waste paper or a combination of the two. Corrugations contain waste paper with or without semi-chemical pulp.

Corrugated and solid fiber boxes are shipping containers.

Construction paper and paperboard, gypsum linerboard are generally made from waste paper.

Paperboards have the following net power requirements:[15]

	Purchased, M BTU for		Recovered,
	Pulp	Papermaking	M BTU
Linerboard	4.0	13.7	13.6
Corrugating Medium	11.2	13.3	.8
Solid Bleached Sulfate Board	12.0	14.0	15.0
Recycle Board	4.0	18.0	-
Construction Paper & Board	4.0	14.0	-

Gordian Associates[13] have also evaluated energy requirements in the production of paper and paperboard. It will be seen that their figures for requirements for purchased electric power and steam depart from those presented above and are substantially lower.

According to Gordian, power needs range between 300 and 400 Kwh per ton of product. 300 Kwh is said to be a good approximate value, and 400 Kwh a maximum. The following schedule is given for details:

Newsprint	300 Kwh per ton
Writing paper	350
Linerboard	325
Folding boxboard	375

Steam requirements appear to diverge more widely:

Newsprint requires	4,500 lb./ton or	5.1 M BTU/ton
Bleached papers	10,000	11
Linerboard	9,000	10

Small quantities of energy are consumed in "converting," i.e. in making a finished product, such as cut paper for stationery, corrugated containers, etc. For example, 80 Kwh per ton are required in making writing paper, and 80 Kwh plus 1.7 M BTU per ton for converting board to corrugated containers.

In view of the fact that the A. D. Little data check so well against official industry data, the foregoing divergent data have been neglected.

5.4 New Processes

In recent years the research effort of the pulp and paper industry has dwelt heavily on improvements in pulp production in order to save energy, reduce emissions, increase pulp yield while maintaining pulp quality. Among the more promising technologies developed are the following:

Oxygen Pulping. The alkaline-oxygen pulp process (AO) is a variant on the kraft cycle, consisting of an alkaline treatment under pressure of wood chips, followed by disc refining while maintaining pressure, washing, and black liquor separation. The pulp is then treated with oxygen under alkaline conditions at 250°F and 10 at. pressure, final washing, and then bleaching.

Advantages are said to be a simpler recycling of the black liquor without treatment and elimination of sulfur emission problems. There is only a small reduction in net fuel consumption: on the basis of Arthur D. Little data[15] (p. 87-88) the AO process requires about 10 million BTU/ADT (47% yield) vs. 11 million BTU (45% yield) for the corresponding kraft operation. Oxygen requirements are 5 lb./t of pulp charged.

The process was found to be sufficiently interesting to build a commercial plant, and there are indications that the investment cost is substantially below that of a conventional facility. The quality of the product is likely to be comparable to standard kraft pulp, once experience has been gained in operating the new process.

Rapson Effluent-free Kraft Process. The Rapson process also attempts to improve the efficiency of the kraft operations, especially with regard to the environment and energy conservation. This is achieved by replacing 70% of the chlorine typically used in the first chlorination step with chlorine dioxide. Water requirements are cut from 25,000 to 4,000 gallons per ton, and only make-up fresh water is needed. All bleach plant effluents are recycled to pulping, which introduces them into the recovery furnace feed. Sodium chloride is recovered from the white liquor.

A special process is employed for chlorine dioxide generation. The only by-product, sodium sulfate (salt cake), is produced at this point; it is crystallized from the sulfuric acid which goes into the dioxide generator. Salt cake is fed to the kraft cycle, the excess being sold or discarded. Adjustments in the standard kraft plant are needed to cope with changes in the materials flow.

Advantages are higher pulp yield (by 1%), brightness and strength. New savings in steam use are considerable (about 2,500 lb./t compared with the conventional kraft operation). Recoveries from bleaching are 260 lb. of organics (probably in the order of 4 million BTU) per ton of bleached pulp, and consequently overall energy savings are considerable: net purchased energy, using Arthur D. Little data[15] (p. 101, 102), converted on the basis of 10,000 BTU/Kwh, is 6.3 million BTU, almost half that required in conventional practice.

Thermo-mechanical Pulping (TMP). Mechanically produced fiber is usually combined with chemical pulp and used in cheap paper that has only a short life expectancy (cost of mechanical pulp is in the $ 80-90, chemical in the $ 150-180/t range[15] (p. 98). In a departure from refiner mechanical pulping (RMP), wood particles are preheated in the TMP process to 130°C and then ground in a pressurized disc refiner. This practice has resulted in a broadening of the raw material base to include wood residues which have hitherto been wasted. The process is quite energy intensive.

5.5 Outlook

In a recent presentation to the Financial Analysts Federation, Benjamin Slatin[24] of the American Paper Institute presented some interesting data on the growth perspectives for the paper industry, which he expects to expand as far as he can see into the future.

Slatin relates trends in the consumption of paper and board to the total economy through the real GNP (i.e. in constant dollars). In the paper industry the market has been a function of the GNP, as shown in 5.5A for 1947 to 1978. The relationship indicates a function of 53,000 tons of new supply of paper and board (i.e. Production + Imports - Exports) per $ million of real GNP. The dip in 1975 and the lower levels since are rather problematic, and to explore the underlying reasons a more detailed evaluation is undertaken.

The industry is broken into large sectors in 5.5B and 5.5C.

The first segment reviewed is that of newsprint, which has been on a downtrend since 1967, in part attributable to a shift from 32 to 30 lb. weight paper in 1974. However, Slatin expects newsprint to grow at the same rate as real GNP, about 3.5% to 4% per year through 1980. Printing and writing is characterized as a strong growth sector (the only dip relates to inventory adjustment in 1975)--it is greatly supported by the demand for computer printout and other business papers. Packaging and industrial grades have been slow: they serve by and large slow-growth markets and have to meet increasing competition from plastics. Also, the demand for tissue is expected to grow more slowly than total economic activity, but is considered subject to promotional efforts and to possible expansion through that of average prosperity.

Fig. 5.5C explores the paperboard grades. The first two grades reviewed depend on the demand for corrugated shipping containers and suggest that on the whole, use of unbleached kraft paperboard is stable within the economy and will continue to track it. The trend of bleached paperboard peaked at the end of the 1960's and grew more slowly than real GNP (plastics made inroads into milk containers and drinking cups). Recycled paperboard has long been declining vs. real GNP, but now the industry feels the pressure to improve utilization of recycled material to help cope with the solid waste problem, and is beginning to realize that waste paper may be swallowed under the boilers of waste-fuelled generating stations.

It seems that Dr. Slatin's near-term forecasting is likely to be correct, and that growth in the use of paper will continue to track the economy in approximately the relationships shown by him. He does point to the significance of the use of paper in business communications and in computing. It is here, however, that changes are likely to occur which over the long term will reduce the demand for paper. Electronics have merely begun to make themselves felt, and the future use of paper will be quite appreciably affected. Technologic change first preserves the application of old devices, designs and resources, then changes to a more efficient mode (How many TV sets are still concealed in "sideboards?").

Plastics, in spite of their petrochemical base, continue to encroach upon the markets of the paper industry. The future will probably see much more of this, and the long term effect of such trends remains to be analyzed.

Finally, demographic trends--the slowing of population growth in the U.S.--must be evaluated in terms of their long term effects on the demand for pulp and paper products.

Fig. 5.5 A

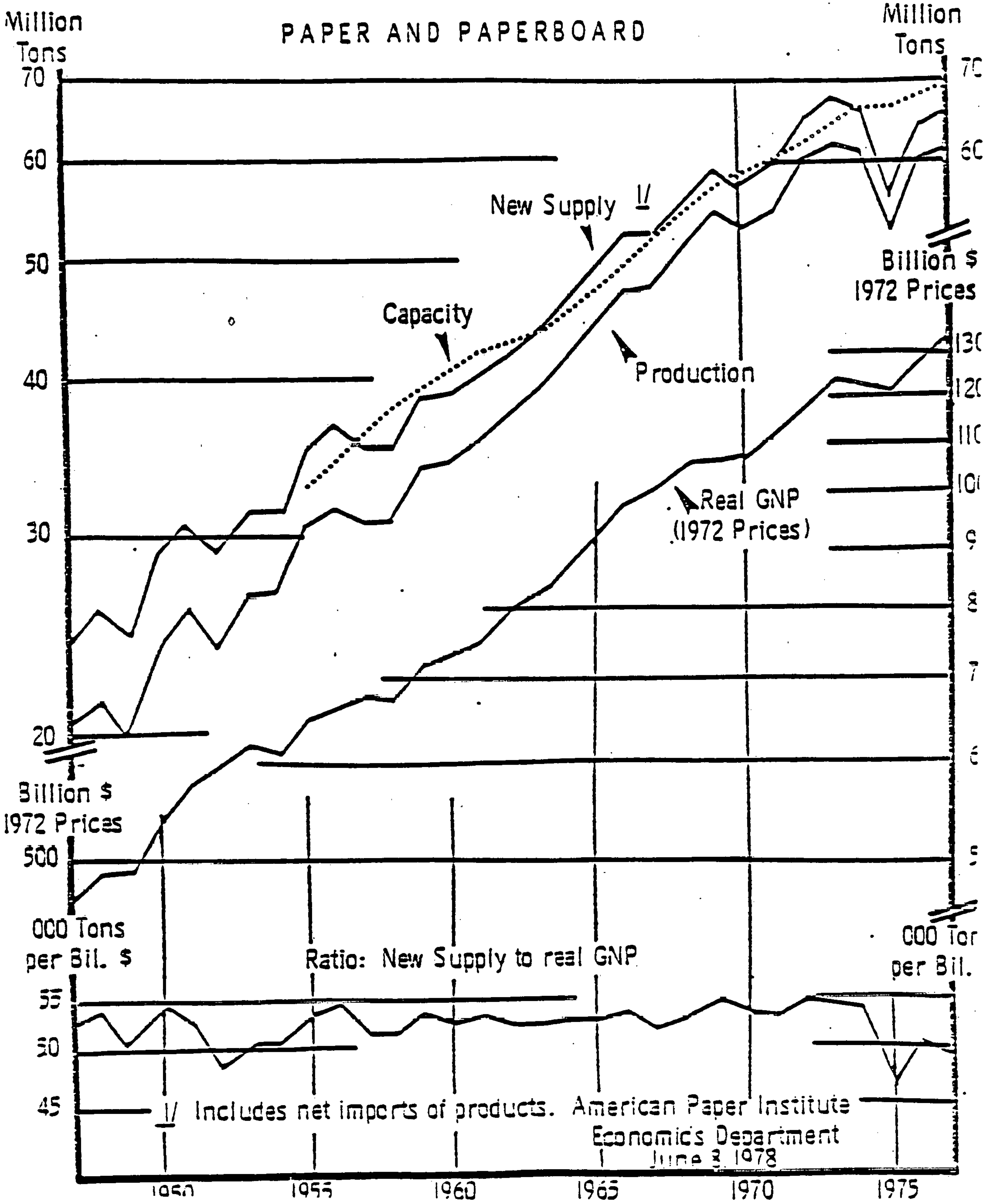

PAPER AND PAPERBOARD
Million Tons
Million Tons
New Supply 1/
Capacity
Production
Real GNP (1972 Prices)
Billion $ 1972 Prices
Billion $ 1972 Prices
000 Tons per Bil. $
000 Tons per Bil.
Ratio: New Supply to real GNP
1/ Includes net imports of products.
American Paper Institute
Economics Department
June 3, 1978
1955
1960
1965
1970
1975

Fig. 5.5 B

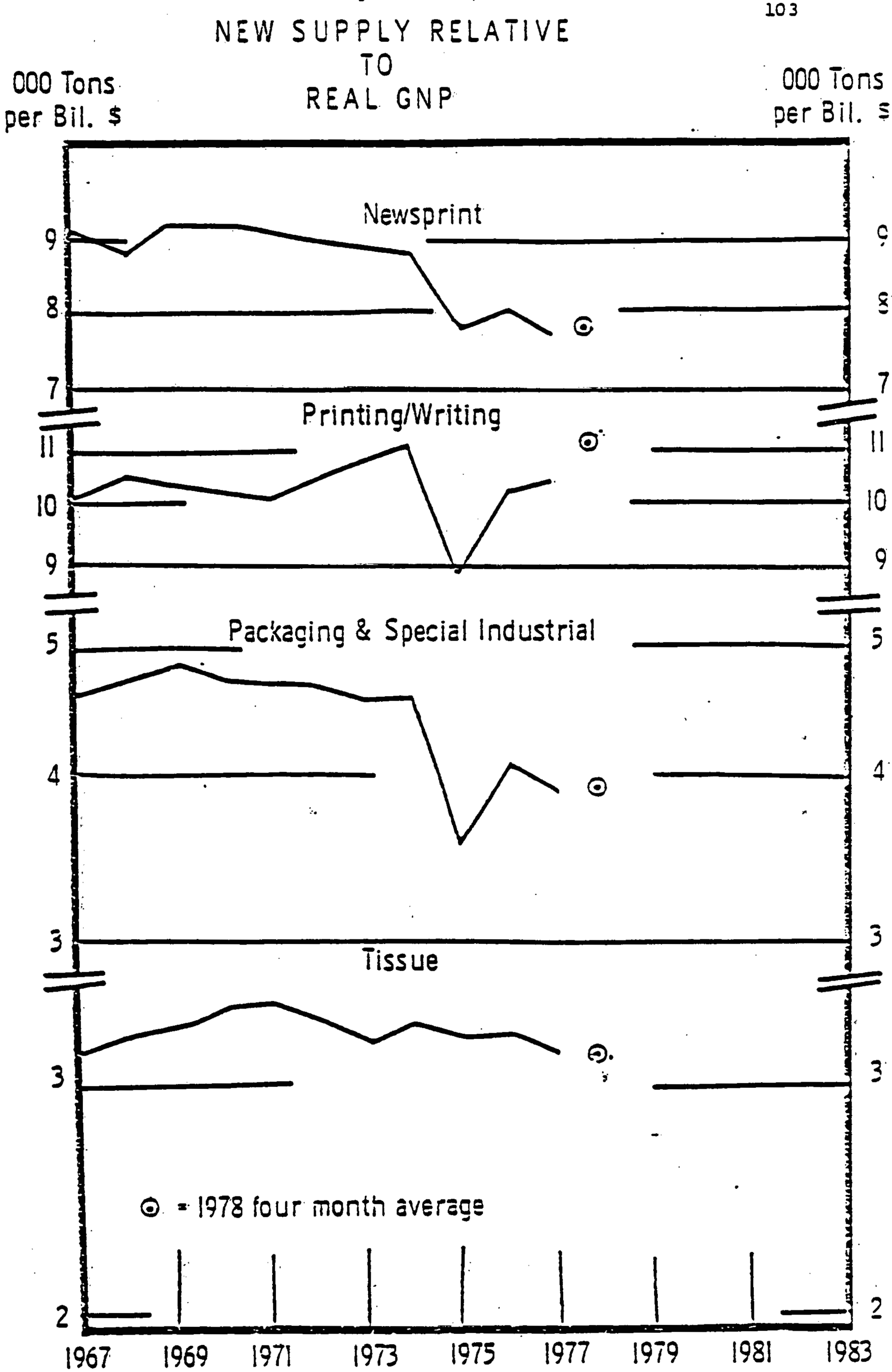
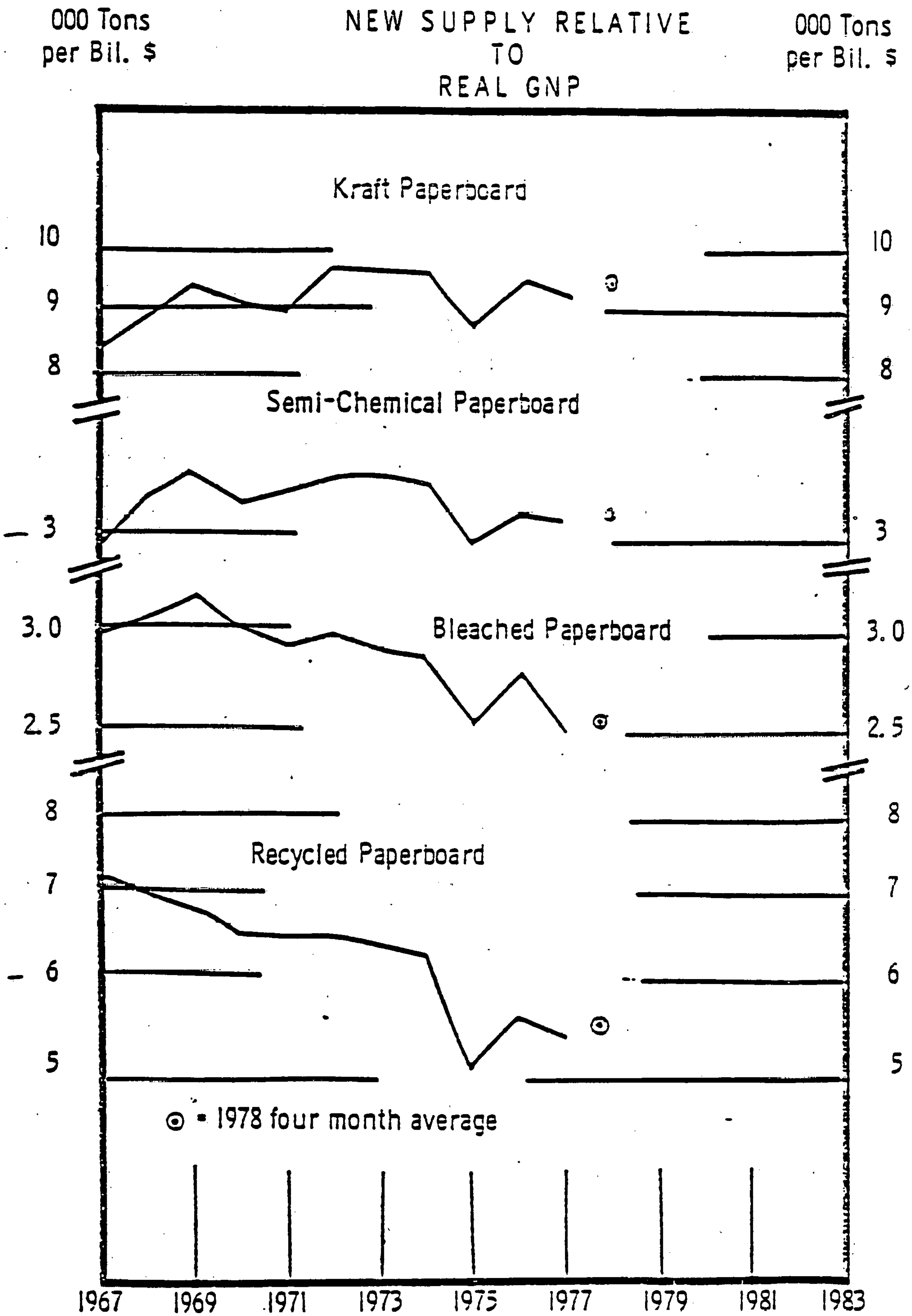

NEW SUPPLY RELATIVE
TO
REAL GNP
000 Tons
per Bil. $
000 Tons
per Bil. $
Newsprint
Printing/Writing
Packaging & Special Industrial
Tissue
9
8
7
11
10
9
5
4
3
3
2
⊙ = 1978 four month average
1967
1969
1971
1973
1975
1977
1979
1981
1983

Fig. 5.5 C


000 Tons
per Bil. $
NEW SUPPLY RELATIVE
TO
REAL GNP
000 Tons
per Bil. $
Kraft Paperboard
10
9
8
Semi-Chemical Paperboard
3
Bleached Paperboard
3.0
2.5
Recycled Paperboard
8
7
6
5
⊙ = 1978 four month average
1967
1969
1971
1973
1975
1977
1979
1981
1983

Appendix A

Arthur D. Little, as reported in footnote 15, provide the attached table, which describes the approximate pulp mixes that went into the 1974 production of major paper products and paperboard.

It will be seen that column A describes the product grades and the type of pulp in the furnish which are quantified in terms of product in column B. The next two Columns, C and D, show the recovered and purchased heat units that were required to produce the pulp needed to make one ton of paper or board, as specified. Columns E and F similarly provide data, on the conversion of pulp to paper and the total purchased heat units per ton of product. Final columns G, H, and I multiply production with total recoveries and purchases, and give a grand total for thermal requirements in the production of paper and paperboard categories.

The purchased energy data are in agreement with the foregoing sections in which thermal requirements are given for the different pulping processes and for the production of different grades of paper and paperboard. (Allowance must be made for bleaching raw pulp.)

By averaging heat requirements for the product groups given, and applying them to 1977 production data, the following Table A has been set up. Table A provides a calculated total purchased BTU requirement of 1,427 million million BTU for the U.S. paper industry in 1977, and comes to within 3% of data presented in Table 5.2.1A. It therefore would appear that the data used by A.D.L. are substantially consistent with industry isage. (In fact the fit is so good as to raise chicken-and-egg type of questions, as between the A. D. Little study and

Table 5.2.1A, which is based on American Paper Institute data. (In fact this conclusion, developed independently through this test, was confirmed by an industry observer who indicated that A. D. Little's findings were predicated on API data.)

The table also provides a test for the data accepted in this report.

Table A: Energy Requirements of the U.S. Paper Industry in 1977.

	Production 1977 M t	Purchased Energy Pulp M BTU/t	Purchased Energy Paper M BTU/t	Total Pulp T BTU	Purchased Energy Paper T BTU	Purchased Energy Total T BTU
Newsprint, etc.	5.0	12.7	14.4	64	72	136
Printing & Writing Papers	12.3	11.3	18.1	139	223	362
Packaging, etc.	5.7	5.6	17.8	32	101	133
Tissue	4.1	10.0	19.0	41	78	119
Linerboard	13.3	4.0	13.7	53	182	235
Corrugating Medium	3.7	11.2	13.3	41	49	90
Solid Bleached Sulfate Board	3.8	12.0	14.0	46	53	99
Recycle Board	7.0	4.0	18.0	28	126	154
Construction Paper & Board	5.5	4.0	14.0	22	77	99
						1427

TABLE III-10

TOTAL ENERGY USAGE, BY MAJOR PROCESS AND PRODUCT GRADE

Product Grade and Pulping Process	1974 Production (000 tons)	Energy Usage, (10^6 Btu/ton) Slush Pulp Recov'd.	Slush Pulp Purch.	Drying (incl. Mkt. Pulp) Purch.	Total Purch.	Annual Total, (10^{12} Btu) Recovered	Purchased	Total
A	B	C	D	E	F	G	H	I
1. Newsprint and Uncoated Groundwood (80% Groundwood)								
Integrated to Kraft & Groundwood	2,700	3.6	13.6	12.7	26.2	10	71	81
Integrated to Sulfite & Groundwood	600	2.8	13.6	12.7	26.3	2	16	18
Integrated to Groundwood only	1,000	3.6	13.6	18.3	31.9	4	32	36
Waste Paper	500	-	4.5	16.7	21.2	-	11	11
TOTAL	4,800	3.3	12.7	14.4	27.1	16	130	146
2. Printing & Writing Papers								
Integrated to Kraft	5,500	15.0	12.0	14.0	26.0	83	143	226
Integrated to Sulfite	1,000	10.0	11.0	14.0	25.0	10	25	35
Integrated to Groundwood (65% Gwd)	1,100	6.0	13.3	19.5	32.8	7	36	43
Waste Paper	1,200	-	4.5	18.0	22.5	-	27	27
Nonintegrated (market pulp)	3,200	15.0	12.0	26.0	38.0	48	122	170
TOTAL	12,000	12.7	11.3	18.1	29.4	148	353	501
3. Packaging, Converting & Special								
Integrated to Bleached Kraft	300	15.0	12.0	15.0	27.0	5	8	13
Integrated to Unbleeched Kraft	4,200	14.0	4.0	15.0	19.0	59	80	139
Waste Paper	500	-	4.0	19.0	23.0	-	12	12
Nonintegrated	900	15.0	12.0	27.0	39.0	14	35	49
TOTAL	5,900	13.2	5.6	17.8	23.4	78	135	213
4. Tissue and Toweling								
Integrated to Bleached Kraft	800	15.0	12.0	12.5	24.5	12	20	32
Integrated to Sulfite	500	10.0	11.0	12.5	23.5	5	12	17
Waste Paper	900	-	4.5	16.5	21.0	-	19	19
Nonintegrated (market pulp)	1,700	15.0	12.0	24.5	36.5	26	62	88
TOTAL	3,900	11.0	10.0	19.0	29.0	43	113	156
5. Linerboard								
Integrated to Unbleached Kraft	12,800	14.0	4.0	13.5	17.5	179	224	403
Waste Paper	400	-	4.5	17.5	22.0	-	9	9
TOTAL	13,200	13.6	4.0	13.7	17.7	179	233	412

TOTAL III-10

TOTAL ENERGY USAGE, BY MAJOR PROCESS AND PRODUCT GRADE (Cont.)

Product Grade and Pulping Process	1974 Production ('000 tons)	Energy Usage, (10^6 Btu/ton) Slush Pulp Recov'd	Slush Pulp Purch.	Drying (incl. Mkt. Pulp) Purch.	Total Purch.	Annual Total, (10^{12} Btu) Recovered	Purchased	Total
6. Corrugating Medium								
Semi-chemical	3,800	1.0	14.0	13.0	27.0	4	103	107
Wastepaper	1,500	--	4.0	17.0	21.0		32	32
TOTAL	5,300	0.8	11.2	14.3	25.5	4	135	139
7. SBS Board								
Integrated to Bleached Kraft	3,700	15.0	12.0	14.0	26.0	56	96	152
8. Recycled Boxboard								
Wastepaper	5,500	-	4.0	18.0	22.0	-	121	121
9. Construction Paper & Board								
65% Defibrated, 35% Wastepaper	5,100	-	4.0	14.0	18.0	-	92	92
10. Other Combination Board								
(Groundwood, Market Pulp, Wastepaper)	1,100	4.4	9.0	18.0	27.0	5	30	35
11. Dissolving Pulp	1,800	17.0	12.8	8.0	20.8	31	37	68
GRAND TOTAL	62,300	9.0			23.5	560	1,475	2,035

Source: Tables III-7, 8, and 9

Appendix B

Table B, which follows, shows the findings for energy consumption as developed by the major studies used in this evaluation. It will be seen that data vary considerably among the literature sources consulted. Owing to the good agreement found for data developed by EPA - A. D. Little with API energy consumption statistics, as indicated in Appendix A, these figures have been relied on more heavily in this report than have the others.

Table 8 : Comparison of Energy Consumption Data for the Pulp & Paper Industries, as Developed by Different Literature Sources.

Reports:	Battelle	Gordian	EPA (A.D. Little)	Middleton	Thermo-Electron
Reference Footnote	17	13	15	12	1
Wood Preparation		Debarking 16 kwh/t Chipping 26 kwh/t	110 kwh/t preparation for Kraft Pulping		
Mechanical Groundwood	1140 kwh/t	1527 kwh/t 1967 kwh/t	1330 - 1510 kwh/t		1000 - 1700 kwh/t
Sulfite Pulp			21 - $28x10^{6}$ BTU (gross)		50 - 100 kwh/t + 4 - 5 $x10^{6}$ BTU (Total= $7-8x10^{6}$ BTU)
Kraft Pulp	$2.8x10^{6}$ BTU/t	350 - 400 kwh/t + $10.7x10^{6}$ BTU/t Recovery of energy at $13.2x10^{6}$ BTU/t of black-liquor solids	320 kwh/t + $12.8x10^{6}$ BTU/t Recovery of energy 17 $x10^{6}$ BTU/t		50 - 100 kwh/t + 3 - $3.5x10^{6}$ BTU/t (Total= $7-9x10^{6}$ BTU/t)
NSSC Pulp		500 kwh/t $5.7x10^{6}$ BTU/t			200 - 500 kwh/t + 1.8 - $2x10^{6}$ BTU/t
Bleaching		Groundwood pulp: 80 kwh + $24x10^{6}$ BTU/t Kraft: 312 kwh + $4.1x10^{6}$ BTU/t	95 kwh/t + $9.1x10^{6}$ BTU/t		80 - 120 kwh/t + 1 - $3x10^{6}$ BTU/t
Paper and Paperboard Production		300 - 400 kwh/t + $5.1x10^{6}$ BTU/t to $10x10^{6}$ BTU/t newsprint - liner-board	12.5 - $18x10^{6}$ BTU/t total forming & drying	(gross?) 31 - $62x10^{6}$ BTU/t 30 - $49x10^{6}$ BTU/t (net) Newsprint to Stationery/Tissue	300 - 400 kwh/t + 5 - $9x10^{6}$ BTU/t

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