file copy.

Rye Grass Straw Utilization in Paper and Fiberboard Products: An Exploratory Investigation

Circular of Information 648
January 1975

Agricultural Experiment Station
Oregon State University, Corvallis

CONTENTS

PREFACE i

SUMMARY.. ii

INTRODUCTION... 1

PLANT SELECTION...................................... 2

DESCRIPTION OF PLANTS................................ 6

CAPITAL ESTIMATES.................................... 10

MANUFACTURING COST ESTIMATES......................... 11

MILL SALES PRICES, AND GROSS SALES ESTIMATES......... 13

GROSS PROFIT AND RETURN ESTIMATES.................... 13

STRAW VERSUS WOOD COMPARISONS........................ 13

PLANT CONVERSION FROM STRAW TO WOOD.................. 17

PLANT CONVERSION FROM WOOD TO STRAW.................. 19

CONCLUSIONS.. 21

ABSTRACT

Sandwell International, Inc., a consulting engineering firm specializing in the design and operation of pulp and paper mills was engaged to provide an initial investigation into the technical and economic feasibility of using ryegrass straw as a substitute for wood residuals in making four types of paper products. Corrugating medium, fine paper, newsprint, and fiberboard were chosen for evaluation. Under 1972 conditions, ryegrass straw was not found competitive as a substitute for wood fiber for use in any of the four types of plants. Straw was not acceptable on technical grounds in production of newsprint.

PREFACE

The Department of Agricultural Economics, Oregon State University, has conducted several research projects which focus on economic issues associated with termination of open field burning for the Willamette Valley grass seed industry. This research report provides an initial investigation into the economic feasibility of using straw as a substitute fiber for wood in the manufacture of pulp and paper in the Pacific Northwest. The study was conducted by Sandwell International, a consulting engineering firm specializing in technical and economic feasibility studies, design and operation of pulp and paper mills. Research funds were provided jointly by the United States Environmental Protection Agency, Washington, D.C., and the Agricultural Experiment Station, Oregon State University, with research supervision provided by Dr. Frank S. Conklin, associate professor of agricultural economics. The Environmental Protection Agency funds were sponsored by the Office of Solid Waste Management, Industrial and Agricultural Wastes Section, Systems Implementation Branch, Hazardous Wastes Management Division, Grant No. G06-EC-00266. Appreciation is expressed for the awarding of the grant. Interpretations expressed in this document are those of Sandwell International, and should not be construed as reflecting policy or sentiments of the granting agencies.

This report is intended for general audiences. It compiles and summarizes two technical documents prepared by Sandwell which are on file in the Department of Agricultural Economics, Oregon State University: (1) Report W2690/1 provides a preliminary economic evaluation of grass straw as a raw material in pulp and paper manufacture, and (2) Report W3063/1 compares straw with wood as alternative raw materials and evaluates plant conversion feasibility.

F. S. C.

SUMMARY

Oregon State University engaged Sandwell to prepare preliminary economic evaluations of potential industrial developments which would utilize some or all of the 336,000 tons per annum of rye grass straw expected to be available when open field burning is prohibited in Oregon by legislative ban after January 1, 1975. Four hypothetical plants which would utilize the straw to produce paper and fiberboard products normally manufactured from wood were selected for study.

The results of the initial study, presented in Report W2690/1, dated January 26, 1972, indicated that none of the straw-based plants would be economically attractive, partly because prevailing market conditions were so poor that wood-based plants would also be uneconomic. Consequently, the University engaged Sandwell to prepare preliminary economic comparisons of the straw-based plants versus wood-based plants to determine what their competitive positions would be under similar, even if unfavorable, market conditions. The results of these studies were presented in Report W3063/1 dated September 28, 1972.

This report consolidates the two studies in a single document for convenient publication, and, therefore, does not contain all the statistical and cost data presented in the original reports. This report contains estimates of plant costs, manufacturing costs, mill net sales, and gross return on investment for the following cases:

Case 1, a straw-based 136,000 tons per annum corrugating medium paper mill, versus Case 1A, a similar capacity wood-based mill.

Case 2, a straw-based 80,000 tons per annum fine paper mill, versus Case 2A, a wood-based integrated 80,000 tons per annum fine paper mill and 85,000 tons per annum bleached softwood kraft market pulp mill. Market pulp has been included in Case 2A to take advantage of the economy of size which would not be feasible for the straw-based mill.

Case 3, a straw-based 170,000 tons per annum newsprint paper mill, versus Case 3A, a wood-based mill which would be capable of producing 200,000 tons per annum on a similar paper machine operating at higher speed with the superior strength of the wood fiber furnish.

Case 4, a straw-based 73 million square feet per annum, (3/4-inch basis), medium density fiberboard plant, versus Case 4A, a similar wood-based plant.

This report includes comments on the potential to substitute straw for wood, and vice versa, for the products under consideration. It also presents comparisons of fiber costs, capital costs, and manufacturing costs for the four products.

Capital and manufacturing cost estimates and mill net sales prices are based on 1972 price and market conditions and an estimated baled straw cost of $15 per ton delivered to the plant. The straw cost includes baling, handling, storage, and transportation charges, but no value for the straw itself. (The rationale is treated in "Technical and Economic Considerations in Shipping Grass Seed Residue to Japan," Oregon Agricultural Experiment Station Circular of Information 638, March 1973.)

The marketability of rye grass straw-based products are unknown at this time. However, assuming 1972 market prices for wood-based products would prevail in all cases for the straw-based products, the economics of the various plants would be as shown in the following summary table.

Annual Gross Profit and Return on Plant Capital Estimates

Plant	Amount: Gross sales $1,000s	Mfg cost $1,000s	Gross[a/] profit $1,000s	Plant capital[b/] $1,000s	Gross return[c/] on plant capital
Corrugating Medium					
- Case 1, Straw.........	13,600	11,900	1,700	43,000	4.0%
- Case 1A, Wood.........	13,600	11,100	2,500	34,000	7.0%
Fine Paper & Pulp					
- Case 2, Straw.........	17,700	14,900	2,800	41,000	7.0%
- Case 2A, Wood.........	30,000	21,400	8,600	78,000	11.0%
Newsprint					
- Case 3, Straw.........	24,700	22,500	2,200	64,000	3.0%
- Case 3A, Wood.........	29,000	21,800	7,200	58,000	12.0%
Fiberboard					
- Case 4, Straw.........	11,700	6,800	4,900	12,000	41.0%
- Case 4A, Wood.........	11,700	5,100	6,600	12,000	55.0%

a/ Gross sales minus manufacturing cost before depreciation, interest, and income taxes.

b/ With no allowance for interest during construction or working capital.

c/ Gross profit as a percentage of plant capital.

The foregoing summary indicates, in each case, a wood-based plant would provide a better return on investment than a straw-based counterpart utilizing straw at $15 per ton.

Corrugating medium, the stiffening material between the plies of container board, possibly offers greater potential use for straw in North American paper products than either fine papers or newsprint. However, assuming a competitive quality product could be made, straw could not cost more than $7.50 per ton for the mill to be economically competitive with a wood-based counterpart using hardwood logs at the 1972 price level of $21 per cord.

A straw-based corrugating medium mill was evaluated utilizing the soda pulping process which indicated a higher capital cost than its wood-based counterpart utilizing the neutral sulphite semi-chemical process. The high silica content of the straw would preclude its being substituted for wood in a corrugating medium mill without first making extensive process and equipment modifications which would not be economically justifiable. Similarly, a straw-based counterpart could not be readily converted to utilize wood in the event of a straw shortage. For these reasons, a straw-based corrugating medium mill would not be an attractive project at this time.

Fine papers such as bond, book, onion skin, writing, and ledger are manufactured with a high straw pulp content in many foreign countries. However, a straw-based fine paper mill with its high unit manufacturing costs would not be economically competitive in North America. The prospects of the product being saleable in large volume would be uncertain. As is the case in corrugating medium mills, the dissimilarities of pulping characteristics and processes preclude the convenient substitution of straw for wood and vice versa in a fine paper mill. For these reasons, it may be concluded a straw-based fine paper mill warrants no further consideration at this time.

No commercial process exists whereby an acceptable quality of newsprint can be manufactured with a high straw content. Furthermore, the hypothetical newsprint plant considered in this study would not be economically competitive even if the product were acceptable. Therefore, a straw-based newsprint project merits no further consideration under these conditions.

A straw-based medium density fiberboard plant, if it could produce a premium quality product for the furniture industry, would be economic as long as the current high mill net sales price prevails. However, such a plant would have to receive straw for about 50 cents per ton under 1972 conditions to be economically competitive with similar plants utilizing wood residuals. In the event of a straw shortage, a fiberboard plant probably could be more readily converted to utilize wood than could a pulp and paper mill, and, therefore, could be a less risky investment. Existing wood-based fiberboard plants may present the opportunity to utilize some straw, but this prospect would have to be substantiated by considerable research and pilot plant work.

The potential developments considered herein represent a cross section of plants that might utilize straw for products normally manufactured from pulpwood and wood residuals. None of them would be economically competitive on a non-subsidized basis, and the acceptance of their products on the North American market would be unknown and highly speculative factors. Furthermore, with the exception of medium density fiberboard, these capital intensive plants would be entirely dependent on straw supplies which may be drastically affected by changing conditions of seed markets, farming procedures, weather, collection costs, and alternative uses for straw. For these reasons, it seems unlikely large straw-based manufacturing plants would be considered attractive investments by the private sector unless technology advancement and relative prices of raw materials existing in 1972 were to be altered markedly.

RYE GRASS STRAW UTILIZATION IN PAPER AND FIBERBOARD PRODUCTS: AN EXPLORATORY INVESTIGATION

INTRODUCTION

Straw consumption in pulp and paper manufacture has increased in a number of countries throughout the world where more suitable fibers are not economically available. Commercial use of straw has declined to the point of negligibility, however, in the U.S. and Canada. The decline is attributed to the unreliability of supply caused by changes in farming practices, the increasing cost of collection, and product quality considerations. In view of current problems faced by Willamette Valley's grass seed industry, for which utilization of large volumes of straw in commercial channels might prove beneficial, this study was initiated. Its intent is to provide an initial evaluation of the economic feasibility of using grass straw as the fibrous raw material for certain products normally manufactured from wood.

Three objectives are served by this study:

1. To estimate and compare capital investment, manufacturing costs, and gross returns on plant capital for construction of four plants using straw as the raw material and with an accuracy sufficient only to indicate what products might warrant further investigations. The products selected for initial study are corrugating medium, fine papers, newsprint, and panelboard.

2. To compare straw-based plants with comparable wood-based plants to determine approximate competitive positions on the basis of production costs and returns, assuming comparable products in terms of both quantity and price.

3. To comment on the probable technical and economic feasibility of converting existing plants from wood to straw and vice-versa.

PLANT SELECTION

Corrugating medium, fine papers, and fiberboard were selected for preliminary evaluation since they are made from grain straw or bagasse (sugar cane fiber) in countries where more suitable fibers are not economically available. Newsprint was selected since recent developments in the utilization of bagasse in newsprint production may prove successful on a commercial basis and eventually be applicable to the utilization of straw. The prospects of this becoming feasible are uncertain, however.

Eight case study plants are compared:

Case 1, a straw-based 136,000 tons per annum corrugating medium paper mill, versus Case 1A, a similar capacity wood-based mill.

Case 2, a straw-based 80,000 tons per annum fine paper mill, versus Case 2A, a wood-based integrated 80,000 tons per annum fine paper mill and 85,000 tons per annum bleached soft-wood kraft market pulp mill.

Case 3, a straw-based 170,000 tons per annum newsprint paper mill, versus Case 3A, a wood-based mill which would be capable of producing 200,000 tons per annum on a similar paper machine.

Case 4, a straw-based 73 million square feet per annum, 3/4-inch basis medium density fiberboard plant, versus Case 4A, a similar wood-based plant.

The proposed plant capacities were selected on the basis of evaluating plants of a size normally expected to be economic rather than by sizing them to utilize all the available straw or by attempting to judge the ability of the market to absorb the proposed production.

Corrugating Medium - Cases 1 and 1A

Corrugating medium normally contains a high percentage of short-fibered pulp usually produced from hardwoods in North America and from straw or bagasse in countries where other suitable fibrous raw materials are not economically available. It is anticipated that the short-fibered ryegrass straw would lend itself to the development of the physical characteristics, particularly crush strength, required in corrugating medium.

Consideration was given to basing the Case 1 study on pulping straw by the high yield neutral sulphite semi-chemical pulping process commonly used to pulp hardwoods for this product. However, sulphite would not impart any desirable properties to the pulp which could not be obtained by the caustic soda process. It would present greater air pollution problems and chemical recovery would be more expensive because of the silica content in the straw. Capital costs for the more anti-corrosive pulp mill equipment would also be higher. For these reasons, the Case 1 study was based on the soda pulping process, while the Case 1A study was based on the high yield neutral sulphite semi-chemical pulping process.[1/] In both cases, the site-manufactured pulp would be supplemented by repulped waste container board to provide the strength necessary for good paper making.

Spent pulping chemicals in Case 1 would be recovered and recycled by a conventional recovery system modified to minimize silica build-up. In Case 1A, they would be recovered as saltcake in a fluidized bed reactor and sold as make-up chemical to kraft pulp mills in the Pacific Northwest.

[1/] Editor's Note: The technical feasibility of pulping straw with the neutral sulphite semi-chemical (NSSC) process has been demonstrated on a pilot plant basis and reported in "Pulping Characteristics of Willamette Valley Grass Straws," Station Bulletin 617, Agricultural Experiment Station, Oregon State University, Corvallis, November 1974. The technical and economic feasibility of using the NSSC process on a commercial basis has not yet been evaluated, however.

Fine Papers - Cases 2 and 2A

Fine papers were selected for study because they can contain a high percentage of short-fibered pulp and because straw is utilized for fine paper manufacture in other countries.

Consideration was given to basing the Case 2 study on pulping straw by the kraft process but, as is the case for corrugating medium, the presence of sulphur would not improve the pulp quality over that produced by the soda process and air pollution problems would be created. The Case 2 study was, therefore, based on pulping straw by the soda process and bleaching it in three stages with chlorine, caustic, and sodium hypochlorite.

The Case 2A study was based on pulping hardwood by the kraft process to obtain the desired physical characteristics. Since the kraft process would also permit the production of the softwood pulp required in fine paper, it was decided to include the production of bleached market grade softwood pulp to take advantage of plant size economies which would not be possible for the straw-based mill.

Newsprint - Cases 3 and 3A

A newsprint mill development based on utilizing straw pulp instead of conventional groundwood pulp would consume large quantities of straw. This was the prime reason for including such a potential development in the study. To date, there is no proven method of producing a straw pulp sufficiently competitive in cost and quality to permit its substitution for groundwood pulp newsprint.

Consideration was given to basing the study on pulping the straw either by the mechanical process with disc refiners or by the chemi-mechanical Peadco process which is being developed to utilize bagasse for newsprint manufacture. Disc refining experiments conducted by Oregon State University have not yet produced encouraging results and no information is available on the results that might be obtained from straw treated by the Peadco process. Furthermore, no economic chemical recovery system has been developed for the Peadco process. Therefore, on the basis of the current status of pulping developments, it appears that if any process would be worthy of preliminary evaluation for the production of newsprint from straw, it would be the bleached soda process on which the Case 3 study has been based. A three-stage bleaching sequence would be employed.

The Case 3A study was based on producing newsprint from a mixture of purchased semi-bleached kraft pulp and refiner mechanical pulp site-manufactured from softwood chips. A higher production was assumed for the wood-based newsprint mill because the paper machine would likely be operated at higher speed on the superior wood fiber paper.

Medium Density Fiberboard - Case 4 and 4A

Medium density fiberboard manufactured by the dry process was selected as the most suitable fiberboard for study. Wet processes, employed for softboards and hardboards, were not considered because their water pollution problems requiring high capital and operating costs for abatement have caused most plants to turn to dry process manufacture. Furthermore, generally low returns and competitiveness of softboard mills have not been encouraging for a new product.

Studies and tests by Oregon State University have indicated a particleboard of suitable surface characteristics and mechanical properties can be produced from straw. However, a medium density fiberboard plant producing industrial board from straw for the furniture trade would be expected to have better possibilities of competing with established industries and obtaining a competitive price for its product. For these reasons, a medium density fiberboard plant with 360 tons per day nominal capacity was selected for study as Case 4. The Case 4A plant would be comparable to the straw-based plant except with respect to the provisions for processing wood residuals instead of straw.

DESCRIPTION OF PLANTS

No preliminary design work has been undertaken and no tentative site selections have been made for any of the potential developments. The following paragraphs, therefore, describe only the type and nature of the major facilities expected to be required and for which the capital cost estimates are intended to provide.

Site and Services

A site location would be selected as the best compromise for convenience and lowest costs of transportation, water supplies, effluent disposal, and all the other major factors influencing site selection. In each case, the site would be large enough to provide space for raw materials storage and a buffer between the plant and adjacent residential areas. A spur would be provided for railway transportation.

Effluent in the first three cases would be given conventional primary and secondary treatment before being discharged into a river. Effluent from the medium density fiberboard plant would not require treatment.

The usual provisions would be made for fire protection, offices, laboratories, maintenance shops, and mill stores.

Fiber Storage, Handling, and Preparation

Straw would be received in wire bale form and stored in piles about 40 feet high. The storage area would be leveled and compacted and provided with drainage facilities. The base of the piles would be in the order of 500 feet long by 70 feet wide. Passageways 30 feet wide would be left between the piles for access and fire protection. Straw would be reclaimed from storage and conveyed into the straw preparation building where the wires would be removed and the straw would be passed through cutting machines. Capital cost estimates associated with straw preparation allow for both the dry and the wet cleaning processes to remove dirt and other foreign material, but further experiments in straw collection and storage may indicate only dry process cleaning would be essential.

Conventional facilities would be provided for the storage, handling, and preparation of softwood chips, hardwood logs, and sawdust, as required for the wood-based plants. Hardwood logs would be truck delivered, off-loaded by front-end loaders, slashed, debarked, and chipped. Softwood chips and sawdust would be delivered by truck and rail, unloaded by hydraulic dumper, and stored outside.

Each of the paper mills would be equipped to recycle broke and off-grade or damaged paper from the papermaking machines and the finishing room.

Case 1 - Corrugating Medium Paper Mill

The straw-based corrugating medium paper mill would be designed to produce an average of 400 finished tons per day (136,000 tons per annum) from straw pulp and boxboard clippings.

The pulp mill would be designed to produce 320 air dry tons per day of unbleached straw pulp by the soda process. Major equipment would be a two-tube horizontal continuous digester, a three-stage counter-current vacuum drum washing system, a sextuple effect evaporator system, and a chemical recovery boiler and causticizing system.

The stock preparation system would include complete facilities for the pulping, screening, deflaking, cleaning, and thickening of boxboard clippings which would comprise 30 percent of the corrugating medium furnish.

The paper machine would have a maximum trim width of 255 inches at the winder. It would operate in the range of 1,000 to 1,200 feet per minute when producing corrugating medium in the 26 to 33 pound basis weight range.

The rolls of corrugating medium would be weighed and transported either directly to the shipping platform or to temporary on-site warehouse storage.

Case 1A - Corrugating Medium Paper Mill

The wood-based corrugating medium mill would have the same design capacity and would be similar in many respects to the straw-based mill. The major differences would be in the pulping and chemical recovery processes. The wood-based plant would produce pulp from hardwood by the neutral sulphite semi-chemical process and chemicals would be recovered by a fluidized bed reactor.

The stock preparation system, the paper machine, and the roll finishing facilities would be essentially the same as for the Case 1 mill.

Case 2 - Fine Paper Mill

The straw-based fine paper mill would be designed to produce 80,000 finished tons per annum of fine papers from bleached straw pulp and purchased bleached kraft softwood pulp. Production would be 65,000 finished tons per annum of rolls and 15,000 finished tons per annum of sheets and cut size papers.

The pulp mill would be designed to produce 140 air dry tons per day of bleached straw pulp by the soda process. The pulp mill and chemical recovery systems would be similar to those described in Case 1 except that they would be smaller. A three-stage bleaching plant would be required.

The stock preparation plant would include facilities to repulp bales of purchased bleached kraft pulp and to prepare the additives and color.

Average saleable production would be 235 finished tons per day of rolls, sheets, and cut size papers. The paper machine would have a trim width of 210 inches and would operate in the range of 1,200 to 1,800 feet per minute depending on the basis weight of the paper.

Paper rolls would be transferred to a finishing room where they would be either wrapped for shipment or sheeted and packaged.

Case 2A - Fine Paper and Market Pulp Mill

The wood-based fine paper and market pulp mill would be designed to produce 85,000 air dry tons per annum of bleached softwood kraft market pulp and 80,000 finished tons per annum of fine papers. Production of fine papers from bleached hardwood and softwood kraft pulps would be 65,000 finished tons per annum of rolls and 15,000 finished tons per annum of sheets and cut size papers.

The pulp mill would be designed to produce 520 air dry tons per day of kraft pulp from a continuous digester and five-stage bleach plant. Conventional pulp mill and chemical recovery process equipment would be used.

The stock preparation plant, paper machine, paper finishing, paper storage, and shipping facilities would be similar to those described in Case 2.

Case 3 - Newsprint Paper Mill

The straw-based newsprint paper mill would be designed to produce 170,000 finished tons per annum of newsprint from bleached straw pulp and purchased semi-bleached kraft softwood pulp.

The pulp mill would be designed to produce 400 air dry tons per day of bleached pulp by the soda process. The pulp mill, bleach plant, and chemical recovery systems would be similar to those described in Case 2 except that two two-tube continuous digesters would be required and the other facilities would be proportionately larger.

A conventional stock preparation system would be used. It would include equipment to process purchased pulp and to prepare additives and color. The system would be less complex than in Case 2, but would be much larger.

The paper machine would produce an average of 500 finished tons per day of newsprint rolls at a trim width of 360 inches off the winder. The machine would be of conventional modern design with a maximum speed capability of 3,500 feet per minute. The rolls of paper would be discharged to a semi-automatic finishing line for wrapping, weighing, and labeling.

Case 3A - Newsprint Paper Mill

The wood-based newsprint paper mill would be designed to produce 200,000 finished tons per annum of newsprint from refiner groundwood pulp and purchased semi-bleached kraft softwood pulp. The refiner mechanical pulp mill would be operated at higher speed on the superior wood fiber paper.

Case 4 - Medium Density Fiberboard Plant

The straw-based fiberboard plant would produce 73 million square feet per annum, 3/4-inch basis (360 tons per day), medium density board. Straw would be hammermilled and screened and then fed to three parallel systems each comprising a digester, a refiner, a tubular flash dryer, and a rotary blender in which the straw fibers would be blended with resin and wax. The boards would be produced by a conventional system comprising three-zone mat former, pre-press, multiple-platen hot press, unloader, and a rotary cooler. The finishing operation would comprise sanding both surfaces on a wide-belt multiple head sander and cutting up furniture grade core stock to custom sizes on a specialty saw.

Case 4A - Medium Density Fiberboard Plant

The Case 4A wood-based fiberboard plant would be the same as the straw-based plant except for the provisions to store, handle, and process sawdust and shavings instead of straw.

CAPITAL ESTIMATES

The capital estimates for the eight cases are summarized in Table 1.

Table 1. Plant Capital Estimates, 1972 Conditions

	Amount - $ Millions							
Item	Case 1	Case 1A	Case 2	Case 2A	Case 3	Case 3A	Case 4	Case 4A
Structures	9.0	7.4	8.6	14.0	13.0	12.7	2.1	1.9
Equipment	25.4	19.8	24.2	48.4	38.2	33.7	7.5	7.7
Total direct costs	34.4	27.2	32.8	62.4	51.2	46.4	9.6	9.6
Indirect costs	8.6	6.8	8.2	15.6	12.8	11.6	2.4	2.4
Total plant capital a/	43.0	34.0	41.0	78.0	64.0	58.0	12.0	12.0

a/ With no provision for working capital or interest during construction.

As previously noted, no preliminary design work has been undertaken and no pulp and paper mills in existence are entirely comparable to the straw-based mills evaluated herein. However, Sandwell's records contain capital cost data for modern wood-based mills of comparable size which differ from the potential straw-based mills primarily in respect to the handling, storage, preparation, and pulping of the fibrous raw material. This cost data have been adjusted as judged reasonable to allow for differences in the processes and for the effects of plant size and inflation on the costs of structures and equipment. While the capital estimates must be looked upon as "preliminary" estimates, they are judged to be sufficiently accurate for the purposes of this study.

The estimates of direct cost for mill structures and equipment are intended to provide for the invoice cost of material and equipment, including freight, and the payroll cost of hourly paid labor directly employed on the erection of the material and equipment. The estimates of indirect cost are intended to provide for the contractor's overhead and profit, engineering services, and contingencies.

To make the wood-based cases comparable to the straw-based cases, working capital has not been included in the estimates. The working capital has been excluded in the straw-based cases because inventory requirements and the schedule of payment for the straw are not known.

Interest charges on borrowed capital during the construction period have not been included in the estimates because the method of financing is not known at this time.

MANUFACTURING COST ESTIMATES

The estimated manufacturing costs for each case are summarized in Table 2.

Table 2. Manufacturing Cost Estimates, 1972 Conditions

Mill	Units[a]	Fiber	Chemicals	Fuel & power	Other materials	Labor Admin. & overhead	Total[b]
Corrugating Medium							
- Case 1, Straw...	$/FT	32.35	3.15	11.90	8.45	31.65	87.50
- Case 1A, Wood...	$/FT	29.35	5.90	11.40	7.35	27.50	81.50
Fine Paper							
- Case 2, Straw...	$/FT	71.75	23.25	12.50	17.50	61.00	186.00
- Case 2A, Wood...	$/FT	41.25	28.10	12.00	17.50	51.15	150.00
Newsprint							
- Case 3, Straw...	$/FT	66.45	5.90	12.95	14.70	32.00	132.00
- Case 3A, Wood...	$/FT	57.00	3.75	16.60	12.50	19.15	109.00
Fiberboard							
- Case 4, Straw...	$/Msf	27.95	19.60	6.00	6.45	33.00	93.00
- Case 4A, Wood...	$/Msf	6.85	19.60	7.40	6.45	29.70	70.00

[a] FT = Finished ton.
Msf = Thousand square feet.

[b] Gross return on plant capital before depreciation, interest and income taxes.

The cost of rye grass straw has been based on estimates prepared by the University which indicate baled straw could be delivered for $15 per ton to a plant in the straw-growing area.

The quantities of wood, purchased pulp, waste paper, chemicals, and additives have been derived from Sandwell's records of usages in modern mills. Similarly, fuel and electric power consumptions and the allowances for miscellaneous operating supplies and maintenance materials have been derived from operating records of modern mills.

The unit costs of raw materials have been obtained from suppliers and from operating mills in the Pacific Northwest. The electric power unit costs have been obtained from a public utility company. Labor estimates have been based on 4-shift operation and rates of pay have been obtained from Pacific Northwest mills.

Administration and overhead cost estimates cover management, general office expense, accounting, purchasing, sales, plant engineering, indirect labor and salary costs, overtime, property tax and insurance, and sundry overheads.

The manufacturing cost estimates are based on current costs and do not include provision for inflation.

MILL SALES, PRICES, AND GROSS SALES ESTIMATES

The annual mill sales on which the earnings estimates have been based are shown in Table 3. The prices are understood to have been the prevailing net to the mill in 1972 after defraying freight and sales costs. To compare the economics of the two types of plant, no adjustment has been made for the possibility the straw-based products would not command the same prices as the wood-based products.

GROSS PROFIT AND RETURN ESTIMATES

The estimated gross profits and returns for the eight cases are summarized in Table 4.

STRAW VERSUS WOOD COMPARISONS

Plant Capital

The wood-based Case 1A corrugating medium paper mill would have a capital cost about $9 million less than the straw-based mill, primarily because of neutral sulphite semi-chemical process versus alkaline process pulping and chemical recovery equipment. (See footnote 1, p. 3).

The capital costs of the two fine paper mill cases cannot be compared because of the inclusion of market pulp in Case 2A.

TABLE 3. Annual Mill Sales Estimates, 1972 Conditions[a]

Item	Unit	Amount: Cases 1 & 1A	Case 2	Case 2A	Case 3	Case 3A	Cases 4 & 4A
Production							
Rolls...........................	FTPA[b]	136,000	65,000	65,000	170,000	200,000	-
Sheets and cut sizes...........	FTPA	-	15,000	15,000	-	-	-
Bleached pulp..................	ADTPA[c]	-	-	85,000	-	-	-
Fiberboard (3/4")...............	Msf/A[d]	-	-	-	-	-	73,000
Mill net price - 1972							
Rolls...........................	$/FT[e]	100	207	207	145	145	-
Sheets and cut sizes...........	$/FT	-	280	280	-	-	-
Bleached Pulp..................	$/ADT[f]	-	-	145	-	-	-
Fiberboard (3/4")...............	$/Msf[g]	-	-	-	-	-	160
Mill sales......................	$1,000s/A[h]	13,600	17,700	30,000	24,700	29,000	11,700

[a] The estimated annual net sales are based on the plants operating at rated capacity for a full year. This would be difficult to achieve, in all cases, in the first year of operation.

[b] FTPA = Finished tons per annum.

[c] ADTPA = Air dry tons per annum.

[d] Msf/A = Thousand square feet per annum.

[e] $/FT = Dollars per finished ton.

[f] $/ADT = Dollars per air dry ton.

[g] $/Msf = Dollars per thousand square feet.

[h] $1000/A = Thousands of dollars per annum.

TABLE 4. Annual Gross Profit and Return on Plant Capital Estimates, 1972 Conditions

Plant	Annual amount				
	Gross sales $1,000s	Mfg cost $1,000s	Gross profit[a/] $1,000s	Plant capital[b/] $1,000s	Gross return[c/] Percent
Corrugating Medium					
- Case 1, Straw..........	13,600	11,900	1,700	43,000	4.0
- Case 1A, Wood..........	13,600	11,100	2,500	34,000	7.0
Fine Paper & Pulp					
- Case 2, Straw..........	17,700	14,900	2,800	41,000	7.0
- Case 2A, Wood..........	30,000	21,400	8,600	78,000	11.0
Newsprint					
- Case 3, Straw..........	24,700	22,500	2,200	64,000	3.0
- Case 3A, Wood..........	29,000	21,800	7,200	58,000	12.0
Fiberboard					
- Case 4, Straw..........	11,700	6,800	4,900	12,000	41.0
- Case 4A, Wood..........	11,700	5,100	6,600	12,000	55.0

a/ Gross return on plant capital before depreciation, interest, and income taxes.

b/ With no allowances for interest during construction or working capital.

c/ Gross profit as a percentage of plant capital.

The wood-based Case 3A newsprint mill would cost about $6 million less than the straw-based mill, primarily because of the refiner mechanical pulp process versus the alkaline pulping process.

The wood-based Case 4A medium density fiberboard plant would cost about $500,000 less than the straw-based plant primarily because of lower fiber storage and preparation costs.

Manufacturing Costs

The unit manufacturing costs for the eight cases are summarized in Table 5. Further details are presented in Table 2.

Table 5. Manufacturing Cost Comparison, 1972 Conditions

Mill	Units	Amount
Corrugating Medium		
- Case 1, Straw	$/FT	87.50
- Case 1A, Wood	$/FT	81.50
Fine Paper		
- Case 2, Straw	$/FT	186.00
- Case 2A, Wood	$/FT	150.00
Newsprint		
- Case 3, Straw	$/FT	132.00
- Case 3A, Wood	$/FT	109.00
Fiberboard		
- Case 4, Straw	$/Msf	93.00
- Case 4A, Wood	$/Msf	70.00

In each case, the manufacturing cost of the straw-based product is higher than that of the wood-based product. As can be seen in Table 2, there is no common relationship between fiber costs and manufacturing costs for the four products because the fiber resources, labor requirements, and fuel, power and chemical consumptions are different in each case. The costs of the fiber component in manufacturing costs are compared in Table 6. A comparison with Table 5 shows the relative importance of fiber for each case.

TABLE 6. Fiber Cost Comparison, 1972 Conditions

Mill	Annual fiber cost - $1,000s					Fiber cost in finished product
	Straw	Chips or residuals	Hardwood logs	Purchased pulp	Total fiber	
Corrugating Medium						
- Case 1, Straw.....	2,900	-	-	1,500	4,400	$32.35/FT
- Case 1A, Wood.....	-	-	2,730	1,260	3,990	$29.35/FT
Fine Paper						
- Case 2, Straw.....	2,040	-	-	3,700	5,740	$71.75/FT
- Case 2A, Wood.....	-	1,120	2,180	-	3,300	$41.25/FT
Newsprint						
- Case 3, Straw.....	4,300	-	-	7,000	11,300	$66.45/FT
- Case 3A, Wood.....	-	3,700	-	7,700	11,400	$57.00/FT
Fiberboard						
- Case 4, Straw.....	2,040	-	-	-	2,040	$27.95/Msf
- Case 4A, Wood.....	-	500	-	-	500	$ 6.85/Msf

Estimates in Table 6 are based on $15 per ton delivered cost of straw and on assumed straw fiber losses in storage and yields in the processes which would have to be substantiated by full-scale tests.

PLANT CONVERSION FROM STRAW TO WOOD

The medium density fiberboard plant is the only straw-based development studied herein that could be readily converted to utilize wood in the event of a straw shortage.

Presumably the capital cost of a wood preparation plant combined with the high cost of timber would make the utilization of whole logs prohibitively costly for any of the straw-based plants. Therefore, in addition to the specific modifications noted in the following paragraphs, each plant would require a chip handling and storage system to handle purchased chips if it became necessary to switch from straw to wood as the raw fibrous material.

Case 1 - Corrugating Medium Plant

The pulping process in the corrugating medium plant would be switched from soda to neutral sulphite semi-chemical to obtain the desired pulp characteristics. Hardwood chips would be the preferred substitute raw material.

Upon switching to hardwood and the neutral sulphite semi-chemical process, the causticizing plant and lime kiln would become redundant. New equipment would be necessary to produce neutral sulphite semi-chemical cooking liquor and to recover sulphur from the boiler flue gases. Modifications to the digester feeders and additional refining capacity would be required.

Assuming the pulp mill equipment already had the anti-corrosive resistance of Type 316 stainless steel, the modifications to pulp hardwood by the neutral sulphite semi-chemical process might cost about $3 million.

Case 2 - Fine Paper Mill

The pulping process in the fine paper mill would be switched to kraft by using saltcake instead of soda ash as the make-up chemical. Hardwood chips would be the preferred substitute raw material. Air pollution abatement equipment (black liquor oxidation plant and facilities to collect and burn the malodorous gases from the blow tank, washers, and evaporator plant) would be required. The bleaching process would be changed from 3-stage chlorine caustic and hypochlorite to 5-stage chlorine, caustic, chlorine-dioxide, caustic, chlorine-dioxide, and a chlorine-dioxide preparation plant would be installed.

The cost of the modifications and additional equipment: about $2 million.

Case 3 - Newsprint Paper Mill

The straw pulping process in the newsprint mill would be switched from soda to produce semi-bleached kraft softwood pulp. This would obviate the necessity of purchasing long-fibered pulp. The chlorine caustic and hypochlorite bleaching sequence would be retained. Air pollution abatement equipment would be installed as in the modifications to Case 2. A 400 tons per day or larger refiner mechanical pulp plant would be installed to utilize softwood chips. One chip handling and storage system would serve both the chemical and the mechanical pulp mills. Depending on the design capacity of the refiner mechanical pulp mill, the plant modifications and additions might cost in the order of $12 - 15 million.

Case 4 - Medium Density Fiberboard

The fiberboard plant could be readily switched to utilize wood residues in the form of chips, shavings, and sawdust. Additional defibering equipment would be required and the digester feed system would need slight modifications.

The cost of the additions and modifications might be in the order of one million dollars.

General Assessment

A brief examination of the effect on production costs of substituting wood for straw indicates that in each case the manufacturing cost would be decreased if wood residues were purchased at prices presently prevailing in the Pacific Northwest.

Switching any one of the plants from straw to wood would create a large demand for wood residues that might not be easily satisfied.

PLANT CONVERSION FROM WOOD TO STRAW

The possibilities of utilizing straw in the wood-based plants without major process and/or equipment modifications other than for straw storage and preparation may be summarized as follows:

Case 1A - Precluded by the high silica content of straw.

Case 2A - Precluded by the dissimilarity of straw and wood fiber chemical pulping characteristics.

Case 3A - Precluded by the dissimilarity of straw and wood fiber mechanical pulping characteristics.

Case 4A - Technically feasible, providing tests prove a competitive quality product can be produced from straw.

Case 1A - Corrugating Medium Plant

The neutral sulphite semi-chemical pulping process in the corrugating medium plant would be suitable to pulp straw, but the quantity of straw would be governed by the amount of silica that could enter the fluidized bed reactor without detriment to its operation. This would be in the order of 15 tons per day of silica based on a manufacturer's recommended maximum of 0.1 percent silica on the weight of chemicals leaving the reactor. The consumption of straw with a silica content of 1 percent would be limited to only 2,000 tons per year; an insignificant amount compared to both the quantity of straw available and the quantity of pulpwood required. The capital cost of the modifications, plus the additional operating costs and problems to utilize this small amount of straw, would be prohibitive.

Case 2A - Fine Paper & Pulp Mill

The pulping characteristics of wood and straw are too dissimilar for the bleached kraft pulp mill operations to be switched from softwood to straw pulping, as they would be from softwood to hardwood pulping. A new 160 air dry tons per day pulp mill complete with all the facilities necessary to store, prepare, cook, wash, and screen the straw would be required at a cost of perhaps $8 million. There would be no economic justification for such an installation, particularly when it would idle the corresponding pulp production capacity of the wood-based mill.

Case 3A - Newsprint Paper Mill

The refiner mechanical pulping process in the wood-based newsprint mill would not lend itself to the utilization of straw until such time as suitable techniques are developed.

Case 4A - Medium Density Fiberboard Plant

Assuming a competitive quality product could be made, the medium density fiberboard plant could be equipped to utilize straw by providing the necessary straw handling and preparation systems and modifying the raw material feed systems as necessary to handle the bulky straw. The capital cost of the additions and modifications might be in the order of one million dollars.

The extra costs of raw material, labor, and fiber losses for the straw-based operation would increase the manufacturing cost by $20 to $25 per thousand square feet (3/4") if straw were delivered to the mill at $15/ton.

CONCLUSIONS

The following conclusions may be drawn from the study:

1. Neither the straw-based nor the wood-based corrugating medium paper mill would be economic under market conditions prevailing at the time of the study. However, assuming competitive quality products could be made and normal market conditions prevailed in terms of relative manufacturing costs, a corrugating medium mill seems to offer the best potential for a straw-based plant to compete with a wood-based counterpart.

2. No further consideration should be given to straw-based fine paper and newsprint paper mills at this time because technological and economic factors both weigh heavily against them.

3. None of the wood-based pulp and paper developments considered in this study appear to be readily or economically adapted to convert to consume significant amounts of straw. However, a wood-based medium density fiberboard plant could be adapted to use large quantities of straw if further investigation proves a competitive quality product can be made.

4. A straw-based medium density fiberboard plant, producing a premium quality product for the furniture industry, would be economical as long as the current high mill net sales price prevails. However, its high manufacturing costs would place it in a poor competitive position with regard to wood-based counterparts.

5. The potential developments considered herein represent a cross section of plants that might utilize straw for products normally manufactured from pulpwood and wood residuals. None of them would be economically competitive and a non-subsidized basis, and the acceptance of their products on the North American market would be unknown and highly speculative factors. Furthermore, with the exception of medium density fiberboard, these capital intensive plants would be entirely dependent on straw supplies which may be drastically affected by changing conditions of seed markets, farming procedures, weather, collection costs, and alternative uses for straw. For these reasons, it seems unlikely large straw-based manufacturing plants would be considered attractive investments by the private sector under 1972 conditions.

6. The medium density fiberboard plant, which seems to offer the best potential from both the technical and economic points of view, would nevertheless have to receive straw for about 50 cents per ton to compete with its wood-based counterpart. This would amount to a subsidy of about $14.50 per ton, assuming the farmers would be paid nothing for the straw.