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ECONOMIC FEASIBILITY OF ESTABLISHING A FLAX TOW OR FLAX SHIVE PELLETING PLANT IN NORTH DAKOTA

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ECONOMIC FEASIBILITY OF ESTABLISHING A FLAX TOW OR FLAX SHIVE PELLETING PLANT IN NORTH DAKOTA

Introduction

Two types of flax are produced in the United States--commercial and seed. Commercial flax is grown for its fiber, achieves a height of three to four feet and averages approximately five bushels of seed per acre. The entire plant, including the root, is removed from the field for processing to obtain maximum fiber length. Fiber that exceeds 10 inches in length is called commercial line fiber and is used in producing fine yarns and textiles. Commercial tow fiber is under 10 inches in length and is used in manufacturing cordage and coarse yarns.

Seed flax is grown principally for the seed. The plant is much shorter than commercial flax and achieves a height of 20 to 30 inches. Seed flax straw is processed into flax tow by removing the woody substance from the fiber in the stem. Flax tow is used primarily in the production of cigarette paper and other fine-textured papers. The woody substance, called shive, is a by-product of flax tow production. Flax shive may be used as a biomass fuel or animal litter due to its combustability and absorbancy characteristics.

Justification

North Dakota is the leading flax-producing state in the United States, harvesting 310,000 acres in 1980. Flax straw is presently left on the field and plowed for tillage purposes or the fiber is removed and used in manufacturing cigarette paper. Flax straw is processed by a decortication unit into 50 percent flax shive and 50 percent tow. The flax tow, which contains approximately 50 percent fiber and 50 percent shive, is then cleaned and the remaining shives removed. The flax shive produced in North Dakota is presently being returned to farmers or transported to a waste disposal site. Presently, shive is considered a waste product and constitutes a disposal problem, creating added expenses for flax straw processing companies.

Flax is produced in North Dakota in substantial quantities, serving as an incentive to locate a flax tow processing facility within the state. A flax tow processing plant is expected to employ a significant number of employees, increasing personal income levels and improving the regional economy. Flax growers' income also would be supplemented through the purchase of straw by tow processors.

Determining alternative uses for flax shive would benefit flax straw processing companies and communities in flax straw processing areas. Flax shive has been determined to have a BTU content comparable to other biomass materials and lignite coal. An analysis of the economic feasibility of constructing a pelleting operation and an investigation of the economics of burning shive pellets are needed to determine if pellets can be produced and burned economically as an alternative fuel source. If pelletizing for fuel source purposes is economically feasible, it possibly could be a substitute heating fuel for many North Dakota residents, small business operations, and institutions. Determining environmental effects of producing and burning shive pellets also is needed to assure that excess pollution is not generated and EPA standards are satisfactorily met.

Scarce fossil fuels and escalating prices have caused increased interest in developing alternative fuels. The possible use of flax shive as an alternative energy source in North Dakota warrants further investigation to determine the feasibility of producing and burning pellets as an alternative energy source.

Study Objectives

The major objective of this study was to determine the economic feasibility of establishing a flax tow and/or a flax shive pelleting facility in North Dakota, and the effects of using shive pellets as a fuel. Specific objectives were to:

1. Determine the acreage, trends, and areas of concentration of flax production in North Dakota.
2. Determine the feasibility of processing flax straw into flax tow for paper at a plant located in North Dakota.
3. Determine the economic feasibility of pelleting flax shive for use as a biomass energy source.

Scope of Study

Flax is produced in large quantities in North Dakota, allowing the potential for a flax tow processing and flax shive pelleting plant to become a new industry in the state. Flax shive has a relatively high BTU content when compared to other biomass materials. Flax tow processing firms consider shive a waste product and pelleting would present an alternative method of disposal.

Two firms currently supply 95 percent of the cigarette paper needs in the United States. These firms are vertically integrated from collecting and decorticating straw to the manufacture of cigarette paper. Financial, marketing, and processing barriers prohibit another firm from entering the industry. (A detailed description of the flax tow industry will follow in a later section of the report.) Therefore, this study will primarily address the economic feasibility of establishing a flax pelleting facility in North Dakota.

This report will provide information concerning requirements for a flax shive pelleting plant to business firms and local communities. Information presented will provide guidance for evaluating the economic feasibility of establishing a flax shive facility in North Dakota and will outline the equipment, financial, and resource requirements.

Production, consumption, and locations of existing flax processing plants will be discussed. Flax acreages and shive production will be analyzed and projected to determine future demand and market potential for shive pellets. Resource and equipment requirements will be examined to determine estimated costs and returns from operating a flax shive pelleting plant. Various biomass burner systems will be identified to project demand for pellets. Past and present facilities burning pellets as a fuel source will be examined to determine alternative methods of burning. An analysis of the environmental impact due to the production and burning of flax shive pellets also will be assessed.

Flax Acreages

Harvested flax acreage has declined drastically in the three major producing states over the past 30 years--from four million acres in 1950 to 700,000 in 1980 (Table 1). Of the three major flax producing states, 44 percent of the acreage was located in North Dakota, 38 percent in South Dakota, and 18 percent in Minnesota in 1980.

Flax production trends by county in North Dakota for 1976 through 1980 are presented in Figure 1. North central and southeastern North Dakota consist of counties with relatively high concentrations of flax straw (15,000 acres and

TABLE 1. HARVESTED FLAX ACREAGE FOR NORTH DAKOTA, SOUTH DAKOTA, AND MINNESOTA, 1970-1980

State	Years										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
	000 acres										
North Dakota	1,644	861	610	933	836	770	500	750	350	460	310
South Dakota	699	425	360	507	509	446	230	330	175	260	265
Minnesota	407	240	156	231	275	250	195	220	142	153	125

SOURCE: USDA Statistical Reporting Service, Crop Production Annual Summaries, 1972-1981, CrPr2-1 (72-81), Washington, D.C.

above in the past five years). The north central section (Area I) includes Bottineau, Ward, McHenry, and Pierce counties, while the southeastern section (Area II) includes Stutsman, Barnes, Emmons, Logan, LaMoure, McIntosh, and Dickey counties. Approximately 109,000 acres of flax were harvested in Area I in 1979, with 44,000 acres (40 percent) harvested in Bottineau County. There were 153,000 acres harvested in Area II in 1979, with 41,500 acres (27 percent) harvested in McIntosh County. Note that 1980 was an atypical crop year in that production and yields were reduced dramatically due to climatic conditions.

The major flax production area in South Dakota was located along the northeastern section of the state (Figure 2). In 1979, at least 15,000 acres of flax were harvested in each of the following counties: Brown, Day, Clark, Codington, Deuel, Hamlin, Brookings, Kingsbury, and Lake. Minnesota has only two counties (Kittson and Roseau) that exceed 15,000 acres of harvested flax (Figure 3).

Canadian production of flax declined from approximately 3.3 to .75 million acres during the 1970-1976 period (Figure 4). Production then increased through 1979 to over 2.3 million acres, making Canada the largest producer of flax straw.

Flax Acreage Projections for North Dakota

Flax acreages were projected to 1990 for the entire state of North Dakota, based on acreage trends from 1970 to 1980. Regression analysis was used to

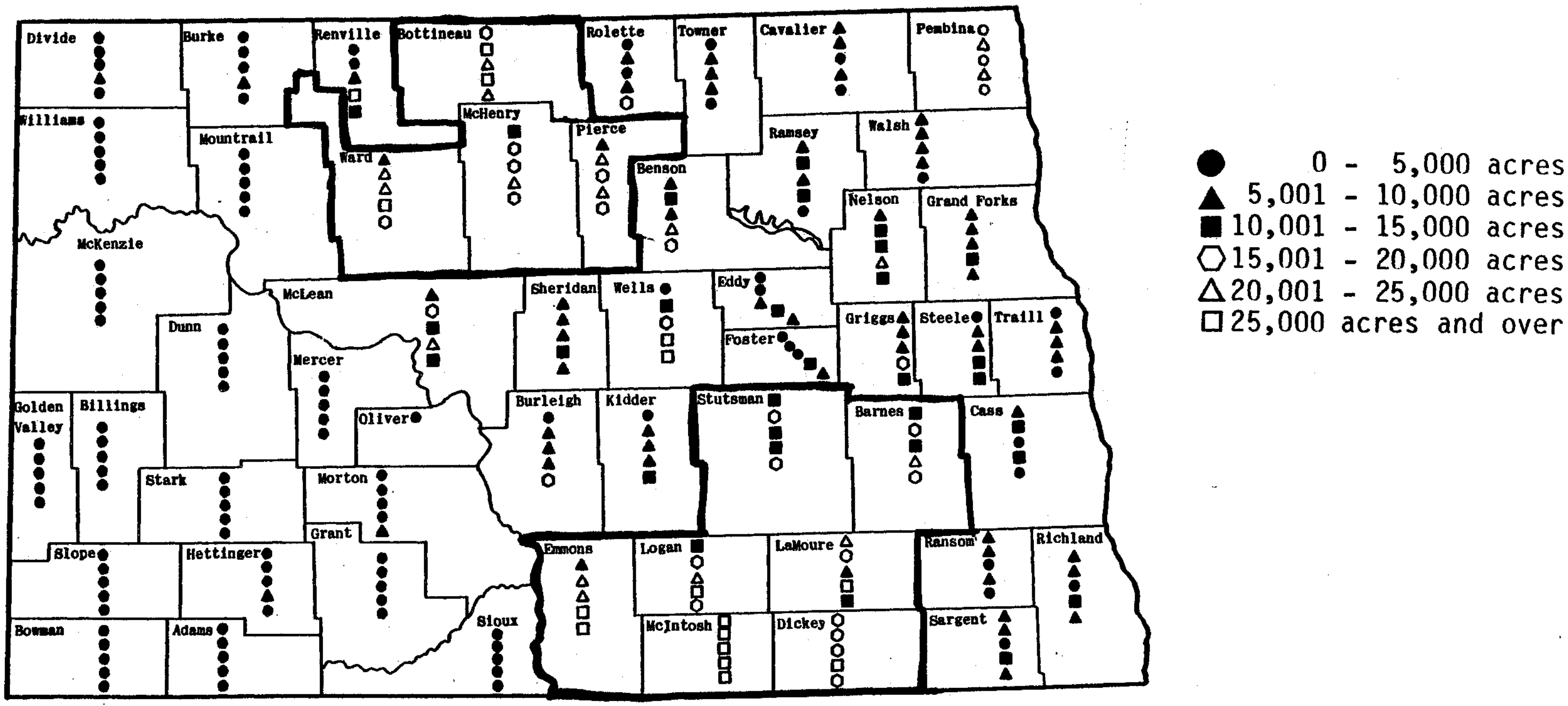

Figure 1. Harvested Flax Acreage by County for 1976 Through 1980, North Dakota*

*The top symbol in each county represents 1980 harvested acreage, with the second, third, fourth, and fifth symbols representing 1979, 1978, 1977, and 1976 acreage, respectively.

SOURCE: North Dakota Crop and Livestock Reporting Service, North Dakota Agricultural Statistics 1980, 1981, Ag Statistics Nos. 45 and 48, Fargo, North Dakota.
________, North Dakota Crop and Livestock Statistics, Ag Statistics Nos. 42 and 44, Fargo, North Dakota.

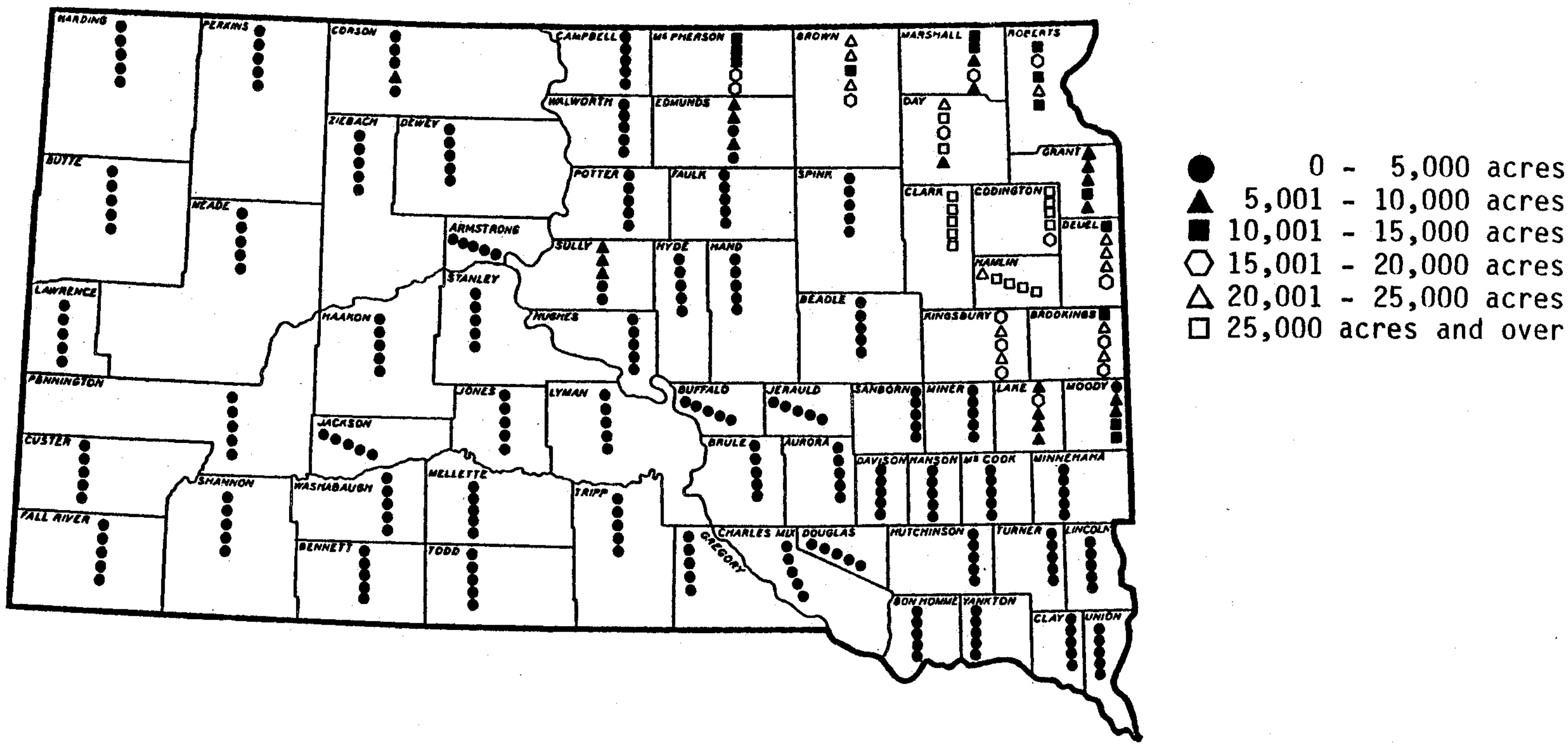

Figure 2. Harvested Flax Acreage by County for 1976 Through 1980, South Dakota*

*The top symbol in each county represents 1980 harvested acreage, with the second, third, fourth, and fifth symbols representing 1979, 1978, 1977, and 1976 acreage, respectively.

SOURCE: South Dakota Crop and Livestock Reporting Service, South Dakota Historic Crop and Livestock Estimates 1976-1980, Sioux Falls, South Dakota, July 1981.

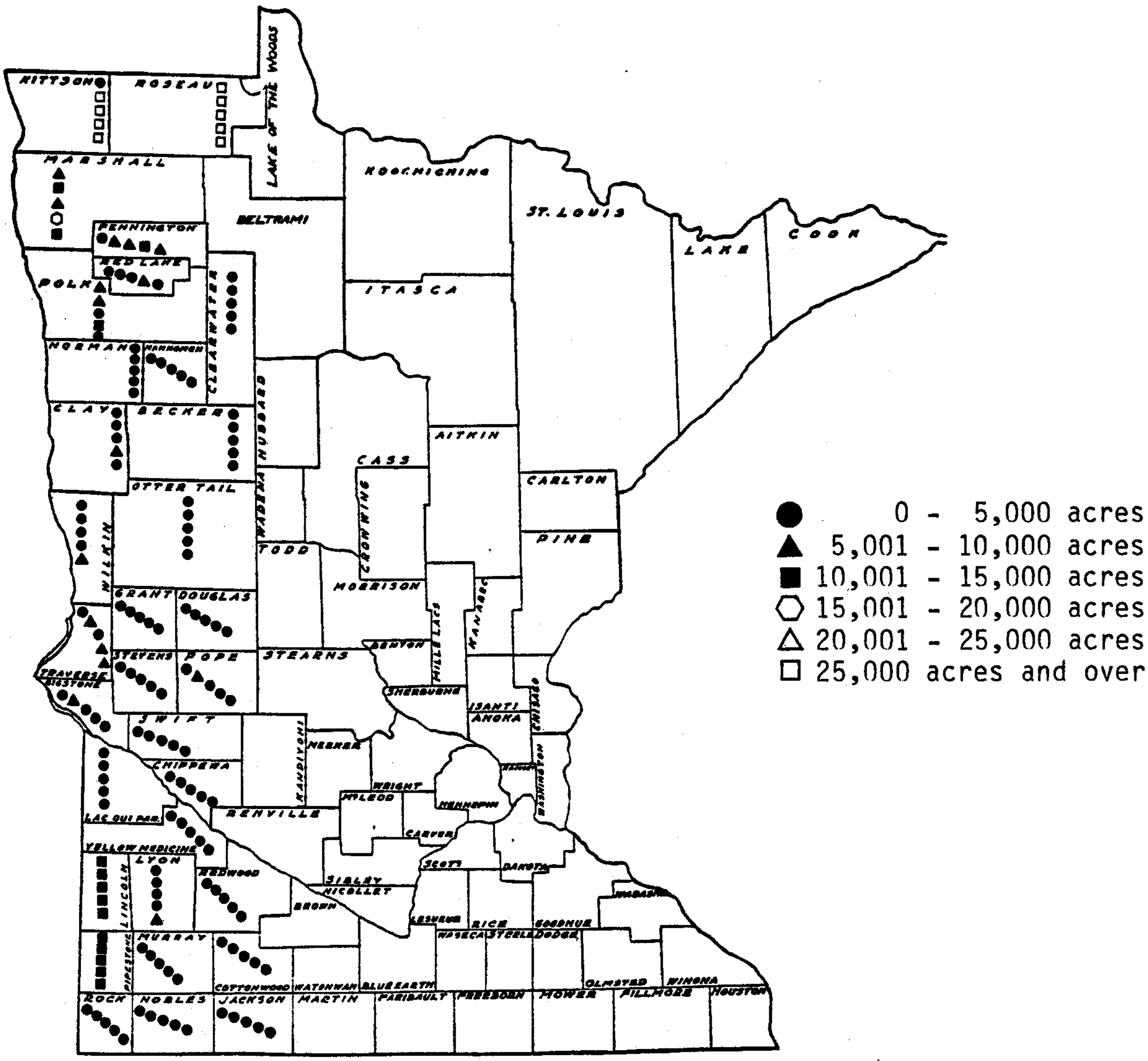

Figure 3. Harvested Flax Acreage by County for 1976 Through 1980, Minnesota*

*The top symbol in each county represents 1980 harvested acreage, with the second, third, fourth, and fifth symbols representing 1979, 1978, 1977, and 1976 acreage, respectively.

SOURCE: Minnesota Agricultural Statistics Service, Minnesota Agricultural Statistics, 1977, 1978, 1979, 1980, 1981, Minnesota Department of Agriculture, St. Paul, Minnesota.

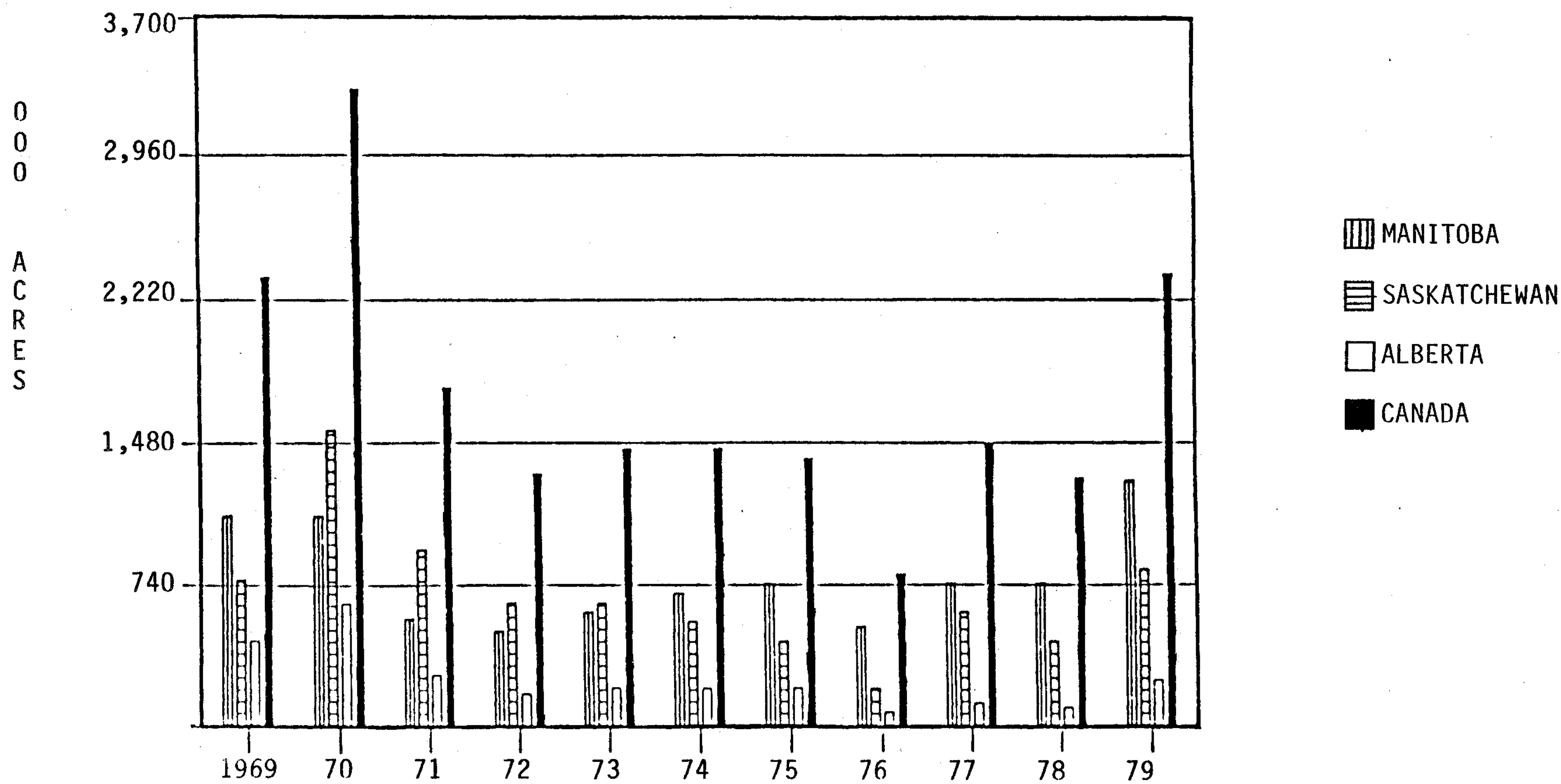

Figure 4. Seeded Flax Acreage For 1969 Through 1979, Canada

SOURCE: Zuk, Bernie, Industrial Services Division, Saskatchewan Research Council, Saskatoon, Saskatchewan.

project flax acreage by determining the best fit of a line to a group of values. A weak relationship developed when a linear trend line was computed, making it a poor method to project flax acreage. Non-linear functions of log, quadratic, and reciprocal functions were analyzed in an attempt to improve accuracy in projecting harvested flax acreage. Final analysis indicated a reciprocal function provided the "best" relationship and was used to project harvested flax acreage to 1990 for North Dakota. Specific county production of flax straw was not estimated since production concentration varies substantially each year. Large variations in annual acreages result in poor modeling equations and large error terms. Harvested flax acreage in North Dakota declined from 1,644,100 acres in 1970 to 310,000 acres in 1980, and was projected to decline to approximately 213,630 harvested acres in 1990 (Table 2).

Projections of concentrated flax areas were difficult to forecast since planted acres vary considerably each year. Flax production is expected to remain relatively stable in the northeast and north central portions of North Dakota for the next several years according to flax straw processing companies. This area provides a large portion of the flax straw presently used by tow producers in North Dakota. The southern area of the state also consistently produces a substantial quantity of flax straw. However, manufacturers presently are utilizing very little of the flax straw production in this area.

Major processing areas of flax straw by the tow processing companies are located in Cavalier, Foster, Bottineau, Wells, Nelson, and Walsh counties of North Dakota, and Roseau County of Minnesota. Flax processing sites in northern North Dakota are located near Langdon, New Rockford, Harvey, Lakota, Bottineau, and Grafton.

Description of Flax Tow and Flax Shive Pelleting Industry

There are two types of flax plants: seed and commercial. Seed flax is the principal variety grown in North Dakota. Utilization of seed-flax fiber has a long history. Domestic use of seed-flax fiber used for cigarette paper developed in the late 1930s. Prior to the 1930s, most cigarette paper used in the United States was imported. It was not until 1938-1939 that companies began manufacturing cigarette paper from domestic flax fiber. Flax

TABLE 2. HISTORIC AND PROJECTED FLAX ACREAGE, NORTH DAKOTA, 1970 TO 1990

Year	Acreage Historic	Acreage Projected
	---000 Acres---	
1970	1,644	1,467.74
1971	861	1,132.21
1972	610	921.71
1973	933	777.34
1974	836	672.16
1975	770	592.13
1976	500	529.18
1977	750	478.38
1978	350	436.51
1979	460	401.42
1980	310	371.57
1981		345.89
1982		323.54
1983		303.93
1984		286.57
1985		271.10
1986		257.23
1987		244.73
1988		233.39
1989		223.07
1990		213.63

decortication involves the removal of the fiber from the stem. By 1962 approximately 200,000 tons, or 30 percent of the economically available straw, was decorticated, providing most of the fibrous material for domestic and export requirements for cigarette paper.[1]

Two major corporations are involved in the production of tow and cigarette paper--Schweitzer, a division of Kimberly-Clark, and Olin Corporation. Each corporation will be discussed with regard to the production of flax tow and cigarette paper in the following section.

Schweitzer Division of Kimberly-Clark Corporation

Schweitzer Division, one of two flax tow processors in the United States, is headquartered in Windom, Minnesota. Kimberly-Clark, an

[1]Goldeborough, G., Seed Flax Straw, Potential for Extending Its Utilization, Agriculture Research Service, U.S. Department of Agriculture, April 1963.

international corporation, primarily produces fiber products such as napkins, tissue, paper towels, and specialty papers.

The following procedures are used by the Schweitzer Division to obtain flax straw. Identification of potentially available flax straw is initiated in early summer to locate the relatively weed-free flax fields. No more than 10 percent weed infestation is allowed due to the texture requirements of cigarette paper. Weed type and infestation levels are evident and herbicides can be applied for weed control when the flax plant is four to eight inches tall. Prospective fields are then visited by a Schweitzer representative to determine if the flax straw can be used for fiber. Farmers are contacted early in the season to determine their willingness to sell flax straw, which allows for maintenance against weed infestation. Purchase of the straw is not finalized until after harvest and after the flax straw quality standards are satisfactorily met. Flax straw is dropped directly behind the combine without employing a chopper or spreader attachment as farmers normally would do. Some farmers pull a packer apparatus behind the combine to keep the straw in place. Schweitzer personnel estimate straw quantity and test for weed content, quality, and fiber strength after the field has been harvested. Straw must exceed 20 inches in length to assure the volume and quality necessary to economically remove the fiber portion of the stem. Hand decortication tests are made on the straw to determine the quality of fiber.

Schweitzer collects straw from the fields with its own baling equipment. A special twine is used to tie the bales since plastics, metals, and other foreign materials cannot be tolerated in the processing cycle. The farm operator is paid 80 percent of the estimated straw value within a few days of the testing procedures. The balance is paid after final tonnage has been determined. Flax straw is presently being purchased for $8 to $12 a ton, depending on location and quality.

Schweitzer processes flax straw with portable decortication units. Straw bales are fed into the decortication units, removing 67 percent of the shive from the flax stem. (Flax straw contains 20 to 25 percent fiber and 75 to 80 percent shive.) The decorticated flax tow has a 50 percent fiber and 50 percent shive content. Schweitzer has five mini-mill decorticators and two larger portable decortication units. The mini-mill units are completely portable and can be assembled to operational status in five minutes. The units, driven by a 450 horsepower diesel engine, are brought directly onto farm sites to decorticate flax straw. Mini-mills process flax straw into tow at a rate of 40 to 45 tons of tow per day, with six to eight individuals operating each machine. Flax straw is processed by mini-mills from May through November.

Schweitzer also has two larger portable decortication units to process flax straw into tow. These units weigh 40 tons each and cost approximately $2,000,000 to fabricate. The larger mills, not as portable as the mini-mills, are transported to concentrated areas of flax production. Straw is hauled to the portable units from an average distance of 40 miles from the mills. These units operate throughout the year and can produce 80 to 90 tons of flax tow per day. A portable 450-kilowatt electric generator is required to operate each portable decorticating unit.

Flax tow is compacted into 300-pound bales and transported from the fields to railroad cars. Schweitzer uses portable loading docks to load tow bales onto 40-ton capacity rail cars which hold an average of 267 bales each. A portable lab accompanies the decortication units to analyze and test the quality of flax tow before shipment. Tow bales are shipped via rail to a Kimberly-Clark cigarette paper manufacturing plant in Spaswig, New Jersey or to different storage locations to await future processing. Schweitzer typically keeps a one year supply of flax tow on reserve in the event of a crop failure.

Flax tow is cleaned and most remaining shives are removed at the paper mill. The fiber is put into large rotary digesters and cooked to remove solubles. Further purification is completed in a vacuum washer. Chlorine and bleach are added to whiten the fiber before processing through a paper machine. The paper is baked dry and tests are made for strength and porosity. (Cigarette paper has to withstand the process of rolling 6,000 cigarettes per minute and be porous enough to let air into the cigarette.) Each roll of finished cigarette paper contains 500 feet of paper and can be rolled into 85,000 cigarettes.

Olin Corporation

The Olin flax straw processing plant is located in Watertown, South Dakota, and, unlike Schweitzer's facilities, is a permanent structure. Olin was in the process of manufacturing portable decortication equipment, which was expected to be operational for the 1981 season. Since Olin had no portable units in 1980, Schweitzer produced about 30,000 tons of Olin's shive located in northern North Dakota. Approximately 50 percent of this shive was Canadian straw that was transported into North Dakota. Since Olin's portable equipment was expected to be operational for the 1981 season, however, Olin's portable mills will now process the flax straw directly in Canada. The remaining 12,000 to 15,000 tons of shive will continue to be produced in the northern portion of North Dakota with a very small percentage of the flax straw processed in the southern portion of the state.

Flax straw is transported from a 175-mile radius to the Watertown-based plant for processing. Baling of the straw is accomplished by Olin employees and farmers. Prices paid to farmers for flax straw, according to Olin, range from $6 to $12 per ton, depending on distance from the plant and quality of the straw.

The flax tow plant at Watertown produces 30,000 tons of tow per year with a 50 percent fiber and 50 percent shive content. Average production of tow per day is 165 tons. Flax tow is compacted into 300-pound bales and shipped to an Olin-owned paper mill at Pisgah Forest, North Carolina, for further processing.

Olin's Watertown plant sells its annual production of 30,000 tons of shive to a private company which in turn markets the shive. The shive generally is sold to individuals for bedding or sold to a company which pellets the shive for use as a heat source. Approximately 80 to 85 percent of the shive Olin produces in Watertown is indirectly marketed to farmers for use as feed or bedding. The majority of shive is used as bedding because of its high absorbancy characteristics.

Summary of Tow Processing Firms

The Olin Corporation and Schweitzer Division are the only manufacturers of flax tow and cigarette paper in the United States. The two corporations supply 95 percent of the cigarette paper required by the tobacco industry in the United States. Both corporations are completely integrated, from collecting and decorticating straw to the manufacture of cigarette paper. The Olin Corporation produces 50,000 to 60,000 tons of tow and is the largest producer of cigarette paper in the United States, supplying over half of the domestic requirements.

The possibility of another firm successfully entering the flax straw processing industry and competing with the Schweitzer Division and Olin Corporation seems unlikely. Financial, marketing, and processing barriers would prohibit another firm from entering the flax tow industry. Schweitzer has patents on its decortication equipment, making it difficult for a new firm to obtain required machinery. The cost involved in fabricating the equipment would probably price a new firm out of the tow market. No market outlet for a new firm would exist due to the present business volume conducted by the two flax tow processing firms. Schweitzer and Olin manufacture enough tow to fulfill the requirements of their paper operations and would have no incentive to purchase tow from another processor.

Flax Shive Pelleting Industry

Flax straw and shive are relatively high in BTU content when compared to other biomass energy sources with BTU contents of 8300 and 7600 per pound, respectively. This compares quite competitively with pine (7950 BTUs per pound), wheat straw (7640 BTUs per pound), and North Dakota lignite coal (6580 BTUs per pound). Although flax straw is higher in BTU content than flax shive, difficulties exist during pelletization. The high fiber content of flax straw causes matting and spherical buildup in front of the pelleting press. This problem becomes so severe that industry experts suggest that pelletization not be undertaken. It would appear that the pelletization of flax shive would be more economical since the shive would be available at selected sites (i.e., at flax straw decortication sites).

The use of pelletized shive as an alternative energy source is a relatively new concept. One plant presently pelletizes flax shive in the United States. Dakota Pelleting Corporation of Watertown, South Dakota, converted a grain elevator located adjacent to Olin Corporation's flax straw processing plant into a flax shive pelleting plant. This location provides for convenient access to the flax shive.

The majority of shive produced by Olin Corporation is sold to a private company which markets the shive to farmers for use as bedding or feed. Only 15 to 20 percent of the shive produced by Olin Corporation at Watertown is converted into pellets by Dakota Pelleting.

Dakota Pelleting purchases shive from a private firm for $11 per ton, then processes it through a pelleting press. Flax shive, which is partially broken down in the decortication process, is further processed through a hammermill or grinder system to reduce shive length before pelletization occurs. Water or steam is added to the shive prior to pelletization to increase the moisture content which aids in the binding process. The shive then is pressed through a quarter-inch die in the pellet mill, forming shive pellets. The pellets are cooled through a cooling system prior to storage due to the high temperatures that occur when shive is pressed through the pelleting die.

Dakota Pelleting currently is producing approximately 5,000 tons of flax shive annually, which it sells for $60 per ton. Litton Industries and the city of Watertown are the principal purchasers of the shive pellets. Litton Industries, located in Sioux Falls, South Dakota, recently added a biomass gasification unit which utilizes shive pellets as the major energy source. (This system will be described in greater detail in a later section of the report.) The city of Watertown utilizes flax shive as an energy source for steam generation in the municipal heat plant.

Model Flax Shive Processing Facility

The majority of flax straw processing in North Dakota occurs in the northeast and north central area of the state. A minimal amount of straw is transported from southeastern and south central North Dakota into South Dakota for processing. Locations of specific sites vary yearly with fluctuations in flax acreage concentrations, making operation of a fixed pelleting plant difficult. Flax straw processors have converted or are in the process of converting almost exclusively to portable decortication units, allowing for versatility in production site locations. This portable equipment allows flax decortication units to follow high quality, high concentration flax production areas.

Flax shive in loose form is low in density, making it difficult and expensive to transport. Annual fluctuations in flax production and concentration areas and flax straw processing locations may cause additional problems and costs in the logistics of a fixed plant location. Therefore, a portable flax shive pelleting facility will be discussed in this study. A or able facility would have the advantage of lower transportation costs compared to a fixed plant site and the ability to move directly to flax decortication sites for processing of the shive pellets.

Three alternative flax shive pelleting facilities will be described in this section of the report followed by a section describing their capital expenditures and operating costs.

Description of Model Flax Shive Pelleting Facilities

Plant capacities for the three model plants chosen were selected in relation to the availability of flax shive in North Dakota, based on estimates received from personnel in the flax tow industry. The facilities would have production capacities of one, five, and ten tons per hour, or 2,080, 10,400, and 20,800 tons annually, based on a 260 working day year (Table 3). The one, five, and ten ton per hour capacity plants will be referred to as small, medium, and large, respectively.

TABLE 3. PRODUCTION CAPABILITIES FOR A SMALL, MEDIUM, AND LARGE FLAX SHIVE PELLETING FACILITY IN NORTH DAKOTA, 1981

Facility Type	Production	
	Per Hour	Annually
	Ton	Ton
Small	1	2,080
Medium	5	10,400
Large	10	20,800

The small facility would have the capacity of processing approximately 10 percent of the shive currently produced in North Dakota, while the medium and large plants would process approximately 50 and 100 percent of the available flax shive in North Dakota, respectively.

The flax shive pelleting equipment would be assembled on a semi-trailer flatbed which allows for movement to flax decortication sites.
Electric motors normally are used to power the pelleting equipment in a fixed plant site operation. However, electrical hookups required for a portable

plant would be inconvenient to facilitate the power needs for the large electrical motors. An alternative to these motors would be a diesel engine which would power the portable pelleting equipment. A small electric generator, driven by the diesel engine, would furnish the required electrical power for small motors on the auger equipment and operating lights.

Flax shive would be conveyed from the flax shive pile left by straw decorticators to the hammermill (Figure 5). The shive would be shredded by the

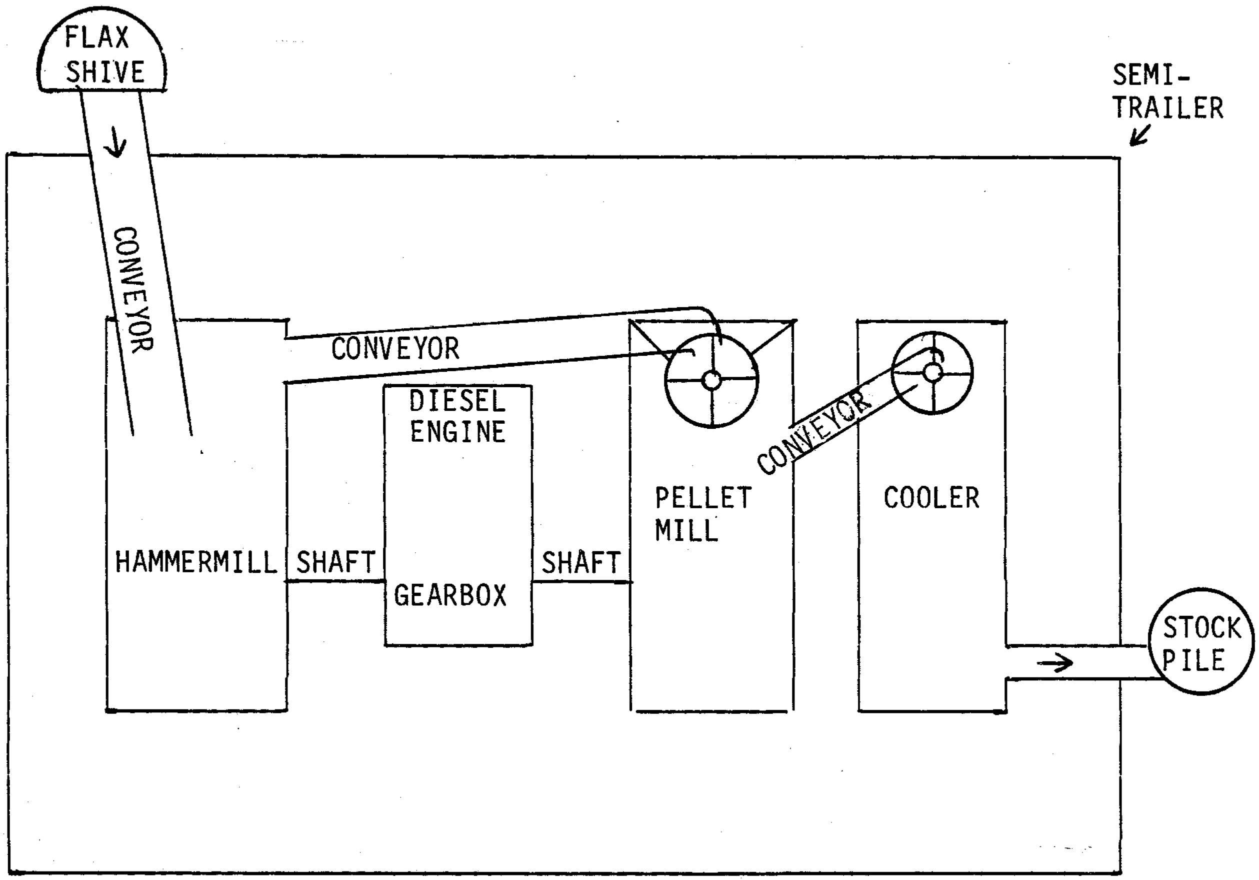

Figure 5. Model Portable Flax Shive Pelleting Facility

hammermill and transferred to the pelleting mill, which would press the shive into one-fourth inch diameter pellets. The pellets then would be conveyed to a cooler where they would be cooled prior to storage to prevent spoilage which may occur if the pellets are stored while still hot. The shive pellets would be covered with a plastic tarp to reduce increases in moisture content. The shive then could be sold directly from the processing site or transported to a central distribution site.

Two distribution alternatives will be considered in the study--at-site and central. Flax shive pellets would be stored at each processing site under the "at-site" distribution system. The flax shive pellets would be distributed from each site to customers. The central distribution system would allow for the transport of flax shive pellets to a central storage and distribution location. This system would require a two- to three-acre site where flax shive pellets would be stored under a plastic tarp. A tractor, loader, and weigh scale would be available for the loading of pellets for customers.

Capital Requirements and Estimated Costs and Returns For Model Flax Shive Pelleting Facilities

Capital requirements and the associated costs and returns for the model flax shive pelleting facilities will be analyzed for two alternative distribution methods: at-site and a central storage and distribution location.

At-Site Distribution Method

The at-site distribution scenario would entail a distribution system whereby the flax shive pellets would be stored and distributed at each processing location. The capital requirements for the at-site location will be described first, followed by estimated costs and returns from simulated flax shive pelleting facilities in North Dakota.

Capital Investment Requirements

Capital investment requirements for the at-site distribution system were identified for the small, medium, and large pelleting facilities (Table 4). Equipment items necessary to operate the different sized facilities were similar except for some deviation in size and cost.

Power requirements for each size pelleting unit are supplied by diesel engines and small electric generators. These engines will accompany each pelleting facility, resulting in a completely portable unit. The small pelleting facility (1 ton/hour) would require a 300 horsepower diesel engine.

TABLE 4. ESTIMATED EQUIPMENT AND INVESTMENT COSTS FOR A SMALL, MEDIUM, AND LARGE FLAX SHIVE PELLETING FACILITY, AT SITE DISTRIBUTION METHOD, NORTH DAKOTA, 1981

Item	Plant Size		
	Small 2,080 tons	Medium 10,400 tons	Large 20,800 tons
	dollars		
Hammermill	13,000	24,000	40,000
Pelleting machine-(includes small electric motors)	30,000	60,000	101,000
Pellet cooler	8,000	16,000	24,000
Conveyors (5)	14,700	14,700	14,700
Diesel engine	18,000	47,294	97,750
Electric generator (1)	3,500	4,000	4,000
Gearbox	13,000	13,000	15,000
Assembly cost	17,000	20,000	23,500
Total cost of pelleting equipment	117,200	198,994	319,950
Semi-tractor	64,000	64,000	64,000
Semi-flatbed trailer (2)	32,000	32,000	32,000
Tractor and loader (1)	23,021	23,021	23,021
Pickup (1)	8,500	8,500	8,500
TOTAL INVESTMENT	244,721	326,515	447,471

SOURCE: Interviews with equipment manufacturers and suppliers.

The engine would supply power to the hammermill, pelleting equipment, and electric generators and would cost approximately $18,000. A medium (5 ton/hour) and large (10 ton/hour) pelleting facility would require a 700-horsepower and 1,200-horsepower diesel engine, respectively. Approximate cost of the 700-horsepower engine was $47,294, while the 1,200-horsepower engine cost $97,750. A central gearbox would be utilized to operate the hammermill and pellet mill from the single engine power source. Estimated cost of the gearbox was $13,000 for the small and medium facility and $15,000 for the large capacity facility.

The cost of the conveyors, which are used to move the shive to the different processing machines, would remain constant for the three different sized facilities. Conveyor manufacturers suggested the use of a 12-inch belt for each sized facility. The same belt and motors would be used for each of the different capacity plants. Manufacturers indicated that a variation in capacity from one to ten tons is not substantial enough to warrant a significant change in the type of equipment used.

A tractor and loader of the same size would be used for the three different sized plants. The small plant would probably not use the tractor to its full capacity, but would require a tractor for moving the shive and shive pellets. However, the large plant would make full use of the tractor's capacity in moving shive and pellets.

Two semi-flatbed trailers would be required for each facility. One trailer would accommodate the pelleting equipment and serve as a portable base. The additional flatbed trailer would transport the tractor and other equipment to different processing sites.

Assembly costs associated with each of the pelleting facilities was $17,000, $20,000, and $23,500 for the small, medium, and large facility. The basic equipment and assembly procedures would be the same for each sized facility according to equipment manufacturers. However, special equipment may be required to handle the larger units, resulting in a slightly higher assembly cost. Total equipment and assembly costs for the small, medium, and large facilities would be $244,721, $326,515, and $447,471, respectively.

Alternative Financing For A Flax Shive Pelleting Facility

North Dakota has several aid programs available to industries that locate within the state as an incentive to attract new industry. The North Dakota Municipal Industrial Development Act was enacted in 1955 for the purpose of attracting new businesses. Under this program, municipalities and/or counties are permitted by the State Legislature to issue either revenue or general obligation bonds for the financing of industrial projects.

This act gives certain advantages to industries which build in North Dakota:[2] 1) interest from the bonds is exempt from North Dakota State and Federal income tax on issues of less than $1 million; 2) the bonds are sold at a lower interest rate than private bonds and therefore lessen construction costs; and 3) corporate income attributable to business done on the lease

[2]Torkelson, David R., North Dakota Industrial Location Facts, North Dakota Economic Development Commission, Bismarck, North Dakota, July 1981.

hold premises may be exempt from North Dakota taxation for a period of five years. Real property may be exempted from taxation after negotiation with any city or county and approval by the State Board of Equalization.

Numerous medium term financing alternatives are available for industry in North Dakota. Some of these include: economic opportunity loans, Farmers Home Administration Business and Industry Loan Program, commercial bank loans, corporate stock, and bond issues.

Estimated Costs and Returns From the Simulated Flax Shive Pelleting Facilities With An At-Site Distribution System

Fixed and variable costs were estimated and returns on investments calculated for each of the three sized flax shive pelleting facilities, given an at-site distribution system. The at-site scenario assumes that the pellets could be sold immediately after processing at the processing site. Data on costs and returns will be analyzed to determine the economic feasibility of processing flax shive into pellets for use as a fuel source.

The costs associated with a portable flax shive pelleting operation were estimated for northeast and north central North Dakota locations since these areas contain the primary flax straw decortication sites. All costs were estimated in 1981 dollars, while revenues for flax shive pellets were based on the break-even price at the distribution site.

Operating Costs

Operating costs are those costs which change with the volume of production. Operating costs associated with flax shive pelleting facilities include flax shive, fuel consumption, repairs, maintenance, labor, and interest on working capital.

Flax Shive. Approximately 15,000 tons of flax shive would be available for processing in northeastern and north central North Dakota; this figure is expected to remain relatively stable for several years, according to flax straw processors. An additional 6,000 tons of flax shive would be available in northwestern Minnesota.

Flax shive can be purchased for $3 per ton at the decortication sites. Annual costs for flax shive purchases would be $6,240, $31,200, and $62,400 for small, medium, and large pelleting facilities, respectively (Table 5).

TABLE 5. ESTIMATED ANNUAL OPERATING AND FIXED COSTS FOR A MODEL FLAX SHIVE PELLETING FACILITY WITH AN AT-SITE DISTRIBUTION SYSTEM, NORTH DAKOTA, 1981

Item	Plant Size					
	Small 2,080 tons		Medium 10,400 tons		Large 20,800 tons	
	Total Cost	Cost Per Ton[a]	Total Cost	Cost Per Ton[a]	Total Cost	Cost Per Ton[a]
	Dollars					
Operating Costs						
Flax Shive	6,240	3.00	31,200	3.00	62,400	3.00
Labor	19,386	9.32	21,923	2.11	38,064	1.83
Fuel	46,800	22.50	80,600	7.75	150,800	7.25
Maintenance						
Diesel Engine	2,713	1.30	4,183	.40	6,590	.32
Pelleting Die Replacement	7,000	3.37	35,000	3.37	73,000	3.51
Bearing & Roller Replacement	3,000	1.44	15,000	1.44	31,500	1.51
Hammer & Screen Replacement	9,360	4.50	46,800	4.50	93,600	4.50
Total Maintenance	22,073	10.61	100,983	9.71	204,690	9.84
Semi-Tractor Trailer	188	.09	1,880	.18	3,760	.18
Interest on Working Capital	1,481	.71	3,288	.32	6,142	.30
Total Operating Costs	96,168	46.23	239,874	23.06	465,856	22.40
Fixed Costs						
Interest on Investment	19,730	9.49	26,324	2.53	36,076	1.73
Insurance	4,508	2.17	5,098	.49	6,348	.31
Depreciation	21,825	10.49	29,186	2.81	40,072	1.93
Management Salary	19,260	9.26	21,320	2.05	25,315	1.22
Total Fixed Costs	65,323	31.41	81,928	7.88	107,811	5.18
Total Cost of Production	161,491	77.64	321,802	30.94	573,667	27.58

[a]Numbers may not add due to rounding.

Labor. Labor requirements for the model pelleting facilities are relatively low. Three employees would be required to operate the small and medium sized plants, while the large plant would require four employees. One person would be employed as a general manager who would oversee the operation, be responsible for record keeping, and coordinate the sale of flax shive pellets. The remaining employees would be semi-skilled laborers whose primary responsiblity would be to load shive and operate the equipment. Estimated annual expenditures for wages and salaries were $38,646, $43,888, and $63,379 for the small, medium, and large facilities (Table 6).

Fuel Consumption. Hourly fuel consumption estimates for the small, medium, and large diesel engines, obtained from equipment suppliers, were 16, 28, and 54 gallons per hour, respectively. Additionally, the diesel tractor with loader would require approximately four gallons of fuel per hour. Estimated annual operating hours for the tractor were 1,040, 1,560, and 2,080 for the small, medium, and large facilities, or 4,160, 6,240, and 8,320 gallons of fuel annually. Total annual fuel consumption required by the diesel engines, including the tractor, ranged from 37,440 gallons for the small facility to 64,480 and 120,640 gallons for the medium and large facilities. Total annual fuel costs, based on a diesel fuel price of $1.25 per gallon, would be $46,800 for the small facility. Annual fuel expenditures would be approximately $80,600 for the medium facility and $150,800 for the large facility.

Repair and Maintenance. Periodic maintenance would be required for the diesel engines used to supply power to the hammer and pellet mills. Maintenance costs include oil, air and oil filters, and engine inspection and overhaul. A maintenance inspection is recommended by manufacturers every 1,200 to 1,500 operating hours, with an engine overhaul suggested every 12,000 to 15,000 operating hours. Total annual maintenance costs for the diesel engine would range from $2,713 for the small facility to $6,590 for the large facility (Table 5).

Repair and maintenance costs are difficult to estimate for the pelleting facility. Maintenance on the pelleting machine would require regular replacement of the die, bearings, and rollers after every 1,000 tons of pellets produced. The cost of die, bearing, and roller replacement does not vary substantially for a one to ten ton per hour facility. However, more frequent replacement is required as the size of facility increases. Annual maintenance

TABLE 6. ESTIMATED ANNUAL WAGES AND SALARIES FOR EMPLOYEES OF PORTABLE FLAX PELLETING FACILITIES, 1981[a]

	Plant Size								
	Small			Medium			Large		
Position	No.	Rate per Hour	Annual Expend.	No.	Rate per Hour	Annual Expend.	No.	Rate per Hour	Annual Expend.
General Manager	1	$9.26	$19,260	1	$10.25	$21,965	1	$12.17	$25,315
Semi-skilled Labor	2	$4.66	19,386	2	$ 5.27	21,923	3	$ 6.10	38,064
Total	3		$38,646	3		$43,888	4		$63,379

[a]Wage rates based on North Dakota Job Service Data.

cost of the pelleting mill was estimated at $10,000, $50,000, and $104,500 for the small, medium, and large facility, respectively (Table 5).

Hammermill maintenance includes replacement of the screen and miscellaneous items, as suggested by manufacturers, at a cost of approximately $4.50 per ton of output. Total annual maintenance cost of the hammermill would range from $9,360 for the small facility to $93,600 for the large facility (Table 5).

Total maintenance costs for the flax shive pelleting facilities are relatively high and remain relatively constant on a cost per ton output basis. Total maintenance costs ranged from $22,073 for the small facility to $204,690 for the large facility while maintenance costs on a per ton of output basis ranged from $9.71 to $10.61.

Semi-Tractor. A semi-tractor would be used to tow the trailer-mounted pelleting equipment and additional flatbed trailer with machinery, such as the tractor with loader, to the pelleting sites. Costs associated with operating the semi-tractor were estimated at $.94 per mile.[3] Mileage requirements by plant size varied according to processing volume and distance to present flax decortication processing sites. Estimated annual mileage requirements for the small, medium, and large facilities would be 200, 2,000, and 4,000 miles. The

[3]Operating costs of the semi-tractor were obtained from Upper Great Plains Transportation Institute personnel.

corresponding transportation costs associated with the small, medium, and large facilities would be $188 (i.e., 200 miles multiplied by $.94), $1,880, and $3,760.

Interest on Working Capital. Capital required for daily business transactions is considered working capital and is difficult to estimate since interest rates have fluctuated radically in past years. Interest on working capital is considered an operating expense and was included in the operating cost portion of the budget.

Borrowed working capital was estimated as one month's operating capital requirements. Monthly operating capital for a small, medium, and large pelleting facility was estimated at $9,871, $21,917, and $40,948. Annual interest charges on working capital for a small facility would be $1,481 (i.e., $9,871 multiplied by 15 percent), assuming an interest rate of 15 percent. Similarly, annual interest charges for the medium and large facilities would be $3,288 and $6,142 (Table 5).

Fixed Costs

Fixed costs are those expenses which remain constant with varying production levels. Interest on investment, insurance, depreciation, management salary, and taxes are considered fixed costs.

Interest on Investment. Capital of $244,721, $326,515, and $447,471 would be required to purchase the small, medium, and large facilities (Table 4). One hundred percent external financing was assumed for purposes of analysis. Interest on external financing, or investment, was considered a long-term debt with a repayment period of 10 years and an interest rate of 12.5 percent. Annual interest on investment charges would average $19,730, $26,324, and $36,076 for the small, medium, and large plants, respectively (Table 5). Economies of size are inherent in that the interest on investment charge would be $9.49 per ton of output for the small facility but only $1.73 per ton of output for the large facility.

Insurance. Estimates of insurance requirements and premiums for the portable pelleting equipment and additional machinery were obtained from local insurance agencies. Equipment coverage and liability insurance were incorporated into the cost estimates. A floater insurance policy was used in the cost estimates since the pelleting equipment was on a portable basis.

Insurance policy rates vary in relation to the mileage traveled when equipment of this nature is on a portable basis. A 200-mile radius estimate was used, based on present locations of available flax shive. Total annual insurance costs, based on these estimates, were $4,508, $5,098, and $6,348 for the small, medium, and large facilities (Table 5).

Depreciation. Depreciation was calculated on equipment for a ten-year period using a straight line depreciation method. An investment tax credit was deducted in the first year and a salvage value of 10 percent of the original purchase price assumed in the tenth year. Annual depreciation for the small facility was estimated at $21,825, while depreciation for the medium and large facilities was estimated at $29,186 and $40,072 (Table 5).

Taxes. The potential exists for certain tax exemptions in North Dakota if a new firm entering the state is not in direct competition with an existing firm. These include a five-year exemption from taxation of real property, state income, and corporate income. It appears that a flax shive pelleting facility located in North Dakota would qualify for these exemptions. The new firm, however, would not be exempt from federal taxation.

Total Cost of Production

Total cost of production refers to all costs associated with plant operations and includes operating and fixed costs. The small facility would accrue a total production cost of $161,491 annually, or $77.64 per ton of output. Similarly, total annual production costs were estimated at $321,802 and $573,667, or $30.94 and $27.58 per ton of output, for the medium and large facilities, respectively.

Revenue Estimates

Revenue generated by the portable flax shive pelleting facility would accrue from the sale of shive pellets. Break-even revenues were computed for each of the different sized portable pelleting plants, where break-even revenue equals cost of production (Table 7). Obviously, an investment will not be made in a venture without a profit (i.e., return on investment). Therefore, a return on investment of 15 percent was computed to determine revenue projections and the sales price required for the shive pellets. Total revenue

TABLE 7. BREAK-EVEN REVENUES FOR MODEL FLAX SHIVE PELLETING FACILITIES WITH AN AT-SITE DISTRIBUTION SYSTEM, NORTH DAKOTA, 1981

	Plant Size								
	Small (2,080 Tons)			Medium (10,400 Tons)			Large (20,800 Tons)		
Item	Total Revenue	Revenue Per Ton	Percent Return on Investment	Total Revenue	Revenue Per Ton	Percent Return on Investment	Total Revenue	Revenue Per Ton	Percent Return on Investment
Break-Even Revenue	$161,491	$77.64	0	$321,802	$30.94	0	$573,667	$27.58	0
Revenue Required For 15 Percent Return on Investment	36,708	17.65	--	48,977	4.71	--	67,121	3.23	--
Break-Even Revenue Plus 15 Percent Return on Investment	$198,199	$95.29	15	$370,779	$35.65	15	$640,788	$30.81	15

required for a 15 percent return on investment was computed as .15 times total investment [for example, .15 x $244,721 (Table 4) = $36,708 (Table 7) for the small plant]. The break-even revenue plus the revenue required for a 15 percent return on investment was computed to determine sales price of pellets required for a fair profit. For example, the break-even revenue of $161,491 for the small facility plus the 15 percent return on investment requirement of $36,708 yielded total revenue of $198,199 (Table 7). The revenue or sales price per ton would be $95.29 for the small facility in order to obtain a 15 percent return on investment. Similarly, sales price per ton of pellets would need to be $35.65 and $30.81 for the medium and large facilities, respectively, to obtain a 15 percent return on investment. The probability of marketing flax shive pellets at these sale prices will be discussed in a later section of the report.

Central Storage and Distribution Method

Previous estimates of capital requirements, costs, and returns were based on pelleting facilities where the flax shive pellets would be stored and distributed at various processing sites. This assumes that the pellets could be sold at the processing sites as they are being produced. An alternative to this distribution method would be to transport pellets to a central storage and distribution site. Additional equipment and costs associated with this type of distribution method will be examined and costs addressed.

Flax shive pellets would be loaded into semi-hopper trailers and transported from the processing locations to a central storage and distribution site. Shive required to operate the small facility at capacity throughout the year could be supplied by one decortication site. Therefore, at-site costs would apply since this site would serve as the central storage and distribution site. Costs associated with the central storage and distribution method were estimated for the medium and large facilities, since shive requirements to operate these facilities at capacity throughout the year would necessitate processing at several flax decortication sites.

Capital Investment Requirements

Additional equipment requirements associated with the central storage and distribution site consist of a tractor with loader, semi-hopper trailer, weigh scale, conveyor, and land. The additional semi-hopper trailer would be required to transport shive pellets to the central storage and distribuiton site, while the additional conveyor would be used to unload the shive on inbound shipments. The tractor with loader would be used to load outbound shipments, while the scale would be used to weigh all inbound and outbound shipments. Land at the central storage and distribution site would constitute two to three acres. Estimated costs of the tractor with loader, semi-hopper trailer, weigh scale, conveyor, and land were $23,021, $17,000, $40,000, $5,000, and $2,000, respectively. Total investment costs for the medium and large flax shive pelleting facilities with a central storage and distribution site would be $412,136 and $533,092 (Table 8).

TABLE 8. ESTIMATED EQUIPMENT AND INVESTMENT COSTS FOR A MEDIUM AND LARGE FLAX SHIVE PELLETING FACILITY, CENTRAL STORAGE AND DISTRIBUTION METHOD, NORTH DAKOTA, 1981

Item	Plant Size	
	Medium 10,400	Large 20,800
	-------dollars--------	
Hammermill	24,000	40,000
Pellet machine-(includes small electric motors)	60,000	101,000
Pellet cooler	16,000	24,000
Conveyors (6)	18,300	18,300
Diesel engine	47,294	97,750
Electric generator	4,000	4,000
Gearbox	13,000	15,000
Assembly cost	20,000	23,500
Total cost of pelleting equipment	202,594	323,550
Weigh scale	40,000	40,000
Land	2,000	2,000
Semi-tractor (1)	64,000	64,000
Semi-flatbed trailer (2)	32,000	32,000
Semi-hopper box trailer (1)	17,000	17,000
Tractors with loaders (2)	46,042	46,042
Pickup	8,500	8,500
TOTAL INVESTMENT	412,136	533,092

SOURCE: Interviews with equipment manufacturers and suppliers.

Estimated Costs and Returns from the Simulated Flax Shive Pelleting Facilities with a Central Storage and Distribution System

Costs associated with a portable flax shive pelleting facility with a central storage and distribution system were estimated for northeast and north central North Dakota due to the proximity of flax straw decortication sites.

Flax shive pelleting sites currently are located near Langdon, New Rockford, Bottineau, Harvey, Lakota, and Grafton, North Dakota and Roseau, Minnesota. The central storage and distribution site was assumed to be located near Devils Lake, North Dakota, which lies in approximately the center of the flax straw processing areas. Shive requirements for the medium facility would be fulfilled at the Langdon, New Rockford, Grafton, Harvey, and Lakota processing sites while the large facility would require shive from all North Dakota processing sites and the Roseau, Minnesota site.

Operating Costs

Two additional semi-skilled workers would be required to transport shive pellets. Estimated annual salaries and wages for the medium and large facilities were $65,811 and $88,755 (Table 9). Fuel costs and maintenance on

TABLE 9. ESTIMATED ANNUAL WAGES AND SALARIES FOR EMPLOYEES OF PORTABLE FLAX PELLETING FACILITIES, CENTRAL STORAGE AND DISTRIBUTION SYSTEM, NORTH DAKOTA, 1981[a]

	Plant Size					
	Medium			Large		
Position	No.	Rate Per Hour	Annual Expenditures	No.	Rate Per Hour	Annual Expenditures
General Manager	1	$10.25	$21,965	1	$12.17	$25,315
Semi-Skilled Laborer	4	$ 5.27	43,846	5	$ 6.10	63,440
TOTAL	5		$65,811	6		$88,755

[a]Wage rates based on North Dakota Job Service data.

diesel engines would increase minimally due to the additional tractor and loader (Table 10).

The major increase in operating costs for this type of facility compared to the at-site facility was attributable to transportation cost increases.

Mileage and transportation costs were computed for transporting flax shive pellets from the processing sites to a central storage and distribution location (Table 11). These costs may fluctuate with the variation in annual flax straw concentrations. Total semi-tractor trailer costs were $56,423 for the medium facility and $92,210 for the large facility (Table 10).

Interest on working capital also increased due to additional operating expenses. Annual interest on operating costs was $4,485 and $7,818 for the medium and large facilities. Total operating costs for the two facilities were estimated at $325,201 and $588,795.

Fixed Costs

Capital of $412,136 and $533,092 would be required to purchase the medium and large facilities (Table 8). Again, 100 percent external financing was assumed with a repayment period of 10 years and a 12.5 percent interest rate. Annual interest charges would average $33,227 and $42,979 for the medium and large facilities, respectively (Table 10). Insurance costs would increase to $5,235 and $6,485 while depreciation would increase to $36,892 and $47,733 for the medium and large plants, respectively. Total annual cost of production for the medium facility would be $422,520 and $711,307 for the large facility (Table 10).

Revenue Estimates

Again, break-even revenues were computed for the two pelleting facilities plus a 15 percent return on investment. Revenue on sales price per ton of output with a 15 percent return on investment would be $46.57 for the medium facility and $38.04 for the large facility (Table 12).

Marketing of Flax Shive Pellets

The production of flax shive pellets requires a market place for their distribution. Marketing potential was determined by analyzing present utilization and available facilities for burning flax shive pellets.

Various methods can be used to burn flax shive: direct combustion with shive in loose form, direct combustion with shive pelletized or condensed, and gasification of flax shive. Direct combustion is the simplest form of burning

TABLE 10. ESTIMATED ANNUAL OPERATING AND FIXED COSTS FOR A MODEL FLAX SHIVE PELLETING FACILITY WITH A CENTRAL STORAGE AND DISTRIBUITON SYSTEM, NORTH DAKOTA, 1981

	Plant Size			
	Medium 10,400 tons		Large 20,800 tons	
Item	Total Cost	Cost Per Ton[a]	Total Cost	Cost Per Ton[a]
	---Dollars---			
Operating Costs				
Flax Shive	31,200	3.00	62,400	3.00
Labor	43,846	4.22	63,440	3.05
Fuel	88,400	8.50	158,600	7.63
Maintenance				
Diesel Engines	4,047	.39	6,227	.30
Pelleting Die Replacement	35,000	3.37	73,000	3.51
Bearing & Roller Replacement	15,000	1.44	31,500	1.51
Hammer & Screen Replacement	46,800	4.50	93,600	4.50
Total Maintenance	100,847	9.70	204,327	9.82
Semi-tractor Trailer	56,423	5.43	92,210	4.43
Interest on Working Capital	4,485	.43	7,818	.38
Total Operating Costs	325,201	31.27	588,795	28.31
Fixed Costs				
Interest on Investment	33,227	3.19	42,979	2.07
Insurance	5,235	.50	6,485	.31
Depreciation	36,892	3.54	47,733	2.29
Management Salary	21,965	2.11	25,315	1.22
Total Fixed Costs	97,319	9.36	122,512	5.89
Total Cost of Production	422,520	40.63	711,307	34.20

[a]Numbers may not add due to rounding.

TABLE 11. MILEAGE AND TRANSPORTATION COSTS FOR A FLAX SHIVE PELLETING OPERATION WITH A CENTRAL DISTRIBUTION SITE, NORTH DAKOTA, 1981

Processing Site	Production of Shive Pellets	Miles to Devils Lake (round trip)	Number of trips at 24 tons per trip	Cost per Mile[a]	Total Transportation Cost
	(tons)	(miles)		(dollar)	(dollars)
Langdon	2,000	154	83	.94	12,015
New Rockford	2,000	80	83	.94	6,242
Grafton	3,000	180	125	.94	21,150
Harvey	2,000	132	83	.94	10,299
Lakota	2,000	62	83	.94	4,837
Bottineau	4,000	216	167	.94	33,908

[a]Mileage rate obtained from personal contact with Upper Great Plains Transportation Institute personnel, North Dakota State University, Fargo, 1981.

shive. Several furnaces designed to use bulk or baled residue are being developed in the United States and abroad for on-farm or small commercial use in grain drying. Furnaces and gasification units that utilize biomass in condensed form also are being developed.

Present Flax Shive Utilization

Several firms currently are making use of flax shive either in bulk or pelletized form. A Warroad, Minnesota firm utilizes wood chips, sawdust, flax shive, and sunflower hulls in bulk form as a fuel source. These biomass materials are used to heat 400,000 square feet of building space with reportedly substantial cost savings over conventional fuel. The plant uses approximately 250 tons per week which supplies about 30 percent of the plant's heating requirements.[4]

[4]Smetanka, Mary J., "Warroad Firm Taking Advantage of Cheap Fuel Substitutes for Heat," Grand Forks Herald, April 26, 1981.

TABLE 12. BREAK-EVEN REVENUES FOR MODEL FLAX SHIVE PELLETING FACILITIES WITH A CENTRAL STORAGE AND DISTRIBUTION SYSTEM, NORTH DAKOTA, 1981

	Plant Size					
	Medium			Large		
Item	Total Revenue	Revenue Per Ton	Percent Return on Investment	Total Revenue	Revenue Per Ton	Percent Return on Investment
Break-Even Revenue	$422,520	$40.63	0	$711,307	$34.20	0
Revenue Required for 15 Percent Return on Investment	61,820	5.94	--	79,964	3.84	--
Break-Even Revenue plus 15 Percent Return on Investment	$484,340	$46.57	15	$791,271	$38.04	15

A municipal heating plant in Watertown, South Dakota is making use of flax shive pellets which are produced by Dakota Pelleting Corporation. The municipal plant provides heat for several buildings in the downtown area. Flax pellets are mixed with coal and burned in a conventional coal furnace boiler to provide the energy needs.

Litton Industries of Sioux Falls, South Dakota recently added a gasification unit to utilize flax shive pellets produced by Dakota Pelleting Corporation. Approximately 256,000 square feet is heated with a combination of pellets and natural gas. The use of flax shive pellets was so successful that a gasification unit was installed to provide a portion of the heating requirements.

Potential Markets for Flax Shive Pellets

Possible market outlets for flax shive pellets were determined by examining different biomass burner units and comparing BTU contents of various types of fuel. Gasification and direct combustion are two types of burner systems that will be discussed. Burning bulk shive will not be addressed since the study focuses on condensing biomass for use as a fuel source.

Gasification

Gasification is a procedure by which a biomass material is converted into a gas for use as a fuel. The gas produced can be used as a substitute for natural gas with minimal adjustments in gas burner units. Heat required for the pyrolysis process is provided by partial combustion of the biomass material and requires only 5 percent of the heating value in the feedstock. Pyrolysis occurs when 20 percent of the air required for total combustion is present, resulting in an energy gas being formed along with waste char. All char is removed when 25 to 50 percent oxygen is present, resulting in a medium energy gas.[5] Additional oxygen results with total chemical energy in the gas being converted to thermal energy and complete combustion occurring.

Three main types of gasifier systems are produced: updraft, downdraft, and a fluidized bed gasifier.[6] In the updraft system, biomass material is fed into the top and descends through three zones. Air ascends from the bottom through a combustion zone, pyrolysis zone, and drying zone, absorbing gases before leaving the system.

A downdraft gasifier operates similar to the updraft system, except gases flow downward through the oxidation zone. Biomass is entered from the top and undergoes pyrolysis as the material descends. Moisture content becomes critical in this type of system and must be controlled to a maximum of 25 percent. The combustion area is maintained at a temperature of 2900° to 3000° Fahrenheit by controlling amounts of oxygen admitted. A biomass bed filters out most particles and oils, producing a cleaner gas than the updraft method.

The third method is a fluidized bed gasifier in which the bed consists of sand particles which are suspended by upward flow of gases. As the gases flow through the bed, biomass materials appear to float on top. An advantage of this method over other gasifiers is the relatively short processing time required.

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[5]Desrosiers, Raymond E., Process Designs and Cost Estimates for a Medium BTU Gasification Plant Using a Wood Feedstock, SERI/TR-33-151, Solar Energy Research Institute, Golden, Colorado, February 1979, page 7.

[6]Overand, Ralph, Gasification - An Overview, Retrofit 79 proceedings of a workshop on air gasification, SERI/TP-49-183, Solar Energy Research Institute, Seattle, Washington, February 1979, page 3-3 to 3-10.

Direct Combustion

Direct burning of biomass material is another alternative available for using flax pellets as a fuel source. Conventional boiler furnaces may be used with a minimum amount of alterations required. Various high schools in South Dakota have experimented with burning flax pellets in their furnaces as a substitute for coal. Flax pellets were used in combination with coal to keep the BTU content high during colder months, since the BTU content of pellets was less than that of eastern coal which they were burning. Shive pellets were found to burn very clean and complete with little remaining ash.

A unit has been developed that burns biomass or lignite coal very efficiently. The unit was selected for analysis since it is relatively new to the market and can be used to burn either flax shive pellets or lignite coal, both fuels being available in North Dakota. Forced air or hot water heat can be generated from the system. An automated stoker system is used to feed shive pellets onto a plater and is attached to a thermostatically controlled auger to allow for uniform heat control. An automatic ash removal system may be added which removes ash from the burner unit to an outside storage site. A small or medium sized furnace and stoker unit can be purchased for approximately $2,000 to $3,000. The units are designed for household use, but larger units are available for small commercial buildings. Hot water boilers may be utilized but cost $12,000 to $16,000. Stoker and burner plates also may be added to an already existing coal or oil furnace with minor adjustments, reducing the costs of converting to biomass fuels.

Fuel Comparisons

BTU comparisons of biomass residues and fossil fuels were computed to determine the competitiveness of flax shive (Table 13). Flax shive was found to be quite competative with other biomass materials, having a BTU content of approximately 7600 BTUs per pound. A cost comparison of different fuels for one therm of energy at various fuel price levels was computed[7] (Table 14). Flax shive pellets could be produced for $30.81 per ton utilizing the large, at-site pelleting facility with a 15 percent return on investment (Table 7). Assuming a BTU content of 7600 BTUs per pound, one therm of energy from flax

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[7]One therm is equivalent to 100,000 BTUs.

TABLE 13. CALORIMETRIC TESTS COMPARING BTU CONTENT OF DIFFERENT BIOMASS MATERIALS AND FOSSIL FUELS

Type of Fuel	BTU Content/lb.
Flax Shive	7,600
Pine	7,950
Wheat Straw	7,640
Sunflower Stalks	8,000
Sunflower Hulls	8,500
Sunflower Oil Meal	8,900
Sunflower Seeds	11,120
Sunflower Oil	17,100
Barley	8,277
Wheat, Hard Red Spring	8,559
Wheat, Hard Red Winter	7,197
Alfalfa	7,952
Oats Straw	8,590
Lignite Coal (North Dakota)	6,580
Anthracite Coal (Pennsylvania)	14,060
Electricity	3,413/KWH
Natural Gas	1,000 BTU/cu. ft.
Oil #2	135,135/gal.
Propane	91,690/gal.

SOURCES: Larue, Jacob and George Pratt, Utilization of Sunflower Stalks, Proceedings of the Second Sunflower Forum, January 12-13, 1977.
Prill Manufacturing Company, Sheridan, Wyoming.

pellets would cost approximately $.34. This is equivalent to a cost of approximately $26.70 per ton of lignite coal, which currently costs approximately $25 per ton. However, the price for flax shive is estimated excluding transportation costs to the buyer and should be considered when interpreting the results. Current fuel costs for propane, electricity, natural gas, and #2 fuel oil were estimated at $.65 per gallon, $.04 per kwh, $.32 per ccf, and $1.10 per gallon, respectively (Table 14). Assuming a price of $30.81 per ton, flax shive pellets could be used at a substantially lower cost than conventional fuel sources other than coal. The same results were found for the medium, at-site, and large, central storage and distribution facility. The medium, central storage and distribution facility and the small at-site facility could produce and sell pellets at a price ($46.57 and $95.29 per ton, respectively) currently competitive with propane, electricity, and fuel oil.

TABLE 14. COMPARATIVE COSTS FOR DIFFERENT FUELS PRODUCING ONE THERM OF ENERGY ASSUMING VARIOUS FUEL EFFICIENCY[a]

Fuel Type											
Flax Shive		Lignite Coal		Propane		Electricity		Natural Gas		Oil #2	
Price/ ton	Cost/ therm	Price/ ton	Cost/ therm	Price/ gallon	Cost/ therm	Price/ kwh	Cost/ therm	Price/ ccf	Cost/ therm	Price/ gallon	Cost/ therm
----dollar-----		----dollar-----		-----dollar-----		-----dollar-----		-----dollar-----		-----dollar-----	
20	.22	10	.13	.50	.72	.015	.44	.20	.27	1.00	1.05
25	.27	15	.19	.52	.76	.020	.60	.25	.33	1.05	1.10
30	.33	20	.25	.54	.79	.025	.74	.30	.40	1.10	1.16
35	.38	25	.32	.56	.81	.030	.89	.35	.47	1.15	1.21
40	.44	30	.38	.58	.84	.035	1.04	.40	.53	1.20	1.26
45	.49	35	.44	.60	.87	.040	1.18	.45	.60	1.25	1.33
50	.55	40	.51	.62	.89	.045	1.33	.50	.67	1.30	1.37
55	.60	45	.57	.64	.92	.050	1.48	.55	.73	1.35	1.41
60	.66	50	.63	.66	.96	.055	1.62	.60	.80	1.40	1.49
65	.71	55	.69	.68	.99	.060	1.77	.65	.87	1.45	1.53
70	.77	60	.76	.70	1.01	.065	1.92	.70	.93	1.50	1.59
75	.82	65	.82	.72	1.04	.070	2.07	.75	1.00	1.55	1.64

[a]The following fuel efficiencies were used:
Flax Shive - 60 percent
Lignite Coal - 60 percent
Propane - 75 percent
Electricity - 99 percent
Natural gas - 75 percent
#2 Fuel Oil - 70 percent

Although flax shive pellets may marginally compete with lignite coal, there are other advantages that may offset the cost difference. Flax shive pellets burn cleaner than coal with only small puffs of white smoke being produced. The pellets were found to ignite easily, heat faster than coal, and produce comparatively small amounts of ash.[8] Minimal odors and dust were evident in handling flax shive pellets. Chimneys and furnaces were found to remain cleaner from tars and resin buildup than occurs when coal is burned. Flax shive pellets are a fuel source that can be burned in combination with coal or by itself. Another advantage associated with burning flax shive pellets is that the organic waste produced can be utilized as a fertilizer. These advantages of cleaner burning and handling may offset the relatively small cost difference between lignite coal and shive pellets.

The prospect of producing flax shive pellets for use as a fuel source has considerable potential when considering economic and environmental effects. Dakota Pelleting has produced and sold flax shive pellets for use as a fuel source for several years. Numerous schools and industries have burned flax shive pellets and have found them to be an attractive alternative fuel source. The clean burning properties and small amounts of ash make them a favorable fuel when compared to the environmental effects of coal. Technological advances have allowed furnaces to be developed that burn biomass pellets, including flax shive pellets, very efficiently and conveniently. Although flax shive pellets are slightly more expensive than lignite coal, they still remain less costly than fuel oil, natural gas, electricity, and propane. Economic competitiveness of flax shive pellets compared to other fuel sources allows them to be a possible alternative fuel that can be used with existing furnaces with minor adjustments.

Economic Impact

The introduction of a flax shive pelleting facility in North Dakota will have numerous direct and indirect economic impacts on the local communities. Economic impacts of the pelleting facility would accrue to the northeastern and north central areas of the state. Direct expenditures in these regions would

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[8]Hauffe, Rick, "Heating With Flax Goes Back For Many A Year," Watertown Public Opinion, February 6, 1979, page 7.

increase the level of business activity throughout the trade and service sectors of the economy.

Assumptions and Results

The impact of the model flax shive pelleting facilities was estimated using the North Dakota input-output model. The input-output model can be used to estimate gross business volume at the state planning region level. Economic impact was calculated by multiplying the local expenditures by the corresponding sector multipliers (Table 15). An example of how the multipliers (or interdependence coefficients) were used can be illustrated for the household sector (this sector consists principally of wages, salaries, and profits). Each dollar paid to the household sector will generate \$.0674 to the agriculture, livestock sector; \$.0266 to the agriculture, crops sector; and so forth for the remaining sectors. The wages, salaries, and profits will generate \$1.5524 to the household sector (the \$1.00 originally paid to the households plus an additional \$.5524 of wages, salaries, and profits induced via the multiplier process). The gross receipts multiplier is the total gross business volume that \$1.00 of output for final demand will generate in gross business volume in all other sectors. Each sector of the economy has a different set of multipliers.

Economic impacts of potential flax shive pelleting facilities were broken down into two phases--construction and operation. The construction impact refers to the "one-time" total gross business volume generated as a result of the construction of the facilities. Gross business volume generated from the operation of flax shive pelleting facilities will take place each year the facilities are in operation. Gross business volume generated each year the facilities are in operation was assumed to be the same. The impact analysis was computed in terms of 1981 dollars.

Economic Impact Resulting From Construction Phase

Some of the expenditures for equipment and materials were expected to occur out of state, so the multiplier effect would not apply to those expenditures. The remaining materials, equipment, and labor were assumed to be available in the local area. Local expenditures for the construction phase

TABLE 15. INPUT-OUTPUT INTERDEPENDENCE COEFFICIENTS, BASED ON TECHNICAL COEFFICIENTS FOR 17-SECTOR MODEL FOR STATE REGIONS

Sector	Lvstk. (1)	Crops (2)	S&G (3)	Const. (4)	Tran. (5)	C&U (6)	WT&MM. (7)	Ret. (8)	F,I,&RE (9)	B&PS (10)	P&SS (11)	HH (12)	Govt. (13)	Coal (14)	E. Gen. (15)	Pet. Exp./Ext. (16)	Pet. Ref. (17)
1. Ag. Livestock	1.2072	0.0774	0.0445	0.0343	0.0455	0.0379	0.1911	0.0889	0.0617	0.0384	0.0571	0.0674	0.0000	0.0375	0.0250	0.0159	0.0040
2. Ag. Crops	0.3938	1.0921	0.0174	0.0134	0.0178	0.0151	0.6488	0.0317	0.0368	0.0152	0.0229	0.0266	0.0000	0.0284	0.0321	0.0062	0.0016
3. Sand and Gravel Mining	0.0083	0.0068	1.0395	0.0302	0.0092	0.0043	0.0063	0.0024	0.0049	0.0043	0.0050	0.0000	0.0031	0.0019	0.0019	0.0045	0.0007
4. Construction	0.0722	0.0794	0.0521	1.0501	0.0496	0.0653	0.0618	0.0347	0.0740	0.0546	0.0787	0.0902	0.0000	0.0514	0.0320	0.1148	0.0168
5. Transportation	0.0151	0.0113	0.0284	0.0105	1.0079	0.0135	0.0128	0.0104	0.0120	0.0118	0.0100	0.0093	0.0000	0.0082	0.0046	0.0180	0.0063
6. Comm. & Util.	0.0921	0.0836	0.1556	0.0604	0.0839	1.1006	0.0766	0.0529	0.1321	0.1104	0.1192	0.1055	0.0000	0.0707	0.0374	0.0610	0.0166
7. Whls. Trade & Misc. Mfg.	0.5730	0.1612	0.0272	0.0207	0.0277	0.0239	1.7401	0.0452	0.0704	0.0237	0.0362	0.0417	0.0000	0.0617	0.0781	0.0097	0.0125
8. Retail	0.7071	0.8130	0.5232	0.4100	0.5475	0.4317	0.6113	1.2734	0.6764	0.4525	0.6668	0.7447	0.0000	0.3975	0.2254	0.1888	0.0452
9. Fin., Ins., Real Estate	0.1526	0.1677	0.1139	0.0837	0.1204	0.1128	0.1322	0.0577	1.1424	0.1084	0.1401	0.1681	0.0000	0.0767	0.0975	0.0888	0.0101
10. Bus. & Pers. Services	0.0562	0.0684	0.0430	0.0287	0.0461	0.0374	0.0514	0.0194	0.0766	1.0509	0.0455	0.0605	0.0000	0.0287	0.0200	0.0139	0.0055
11. Prof. & Soc. Services	0.0710	0.0643	0.0559	0.0402	0.0519	0.0526	0.0530	0.0276	0.0816	0.0497	1.1026	0.0982	0.0000	0.0491	0.0300	0.0210	0.0055
12. Households	1.0458	0.9642	0.8424	0.6089	0.7876	0.7951	0.7859	0.4034	1.2018	0.7160	1.0437	1.5524	0.0000	0.6630	0.3951	0.3206	0.0623
13. Government	0.0987	0.0957	0.0853	0.0519	0.2583	0.0999	0.0796	0.0394	0.1071	0.0774	0.0881	0.1080	1.0000	0.0603	0.0443	0.0280	0.0004
14. Coal Mining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.1582	0.0003	0.0000
15. Electric Generating	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
16. Pet. Exp./Ext.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0010	1.0981	0.0954
17. Pet. Refining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0168	0.0102	0.0000	1.0000
Gross Receipts Multiplier	4.4931	3.6851	3.0284	2.4430	3.0534	2.7901	4.4509	2.0871	3.6778	2.7133	3.4159	3.0783	1.0000	2.5452	2.1928	1.9245	1.2940

were to two sectors of the economy--retail trade and business and personal services (Table 16). Local construction expenditures included the costs for

TABLE 16. LOCAL EXPENDITURES BY ECONOMIC SECTOR RESULTING FROM CONSTRUCTION OF FLAX SHIVE PELLETING FACILITIES, NORTH DAKOTA, 1981

Sector	Plant Size and Type				
	At Site			Central	
	Small	Medium	Large	Medium	Large
	$000				
Retail	149	179	229	219	269
Business and Personal Service	17	20	24	20	24
Total	166	199	253	239	293

the diesel engine, semi-tractor and trailers, tractors with loaders, pickup, and electric generator. Business and personal service expenditures were for equipment assembly. These expenditures will generate a gross business volume to all sectors of the economy, but the principal impacts will be in the retail trade and household sectors. The economic impact would range from $357,000 for the small, at-site facility to $626,000 for the large, central storage and distribution facility (Table 17). Economic impact from the construction of these facilities is nonrecurring and occurs only over the construction time period, regardless of the length of time.

Economic Impact Resulting From the Operational Phase

The operational phase of flax shive pelleting facilities also will have an impact on the local economy. Operational impacts differ from construction impacts in that operational impacts occur annually and continue to take place as long as the pelleting facilities are in operation, while construction impacts occur only once. The majority of operational expenditures, resulting in an economic impact, would be in the local region. Some operational expenditures would be out of state so they have no impact on the local economy. Local expenditures during the operational phase would accrue to retail,

TABLE 17. ADDITIONAL GROSS BUSINESS VOLUMES OF ECONOMIC SECTORS RESULTING FROM THE CONSTRUCTION OF FLAX SHIVE PELLETING FACILITIES, NORTH DAKOTA, 1981

Resulting Increase in Gross Business Volume by Sector	Plant Size and Type				
	At Site			Central	
	Small	Medium	Large	Medium	Large
	$000				
Retail	198	237	303	288	354
Household	72	86	109	102	126
Other[a]	87	105	131	121	146
Total	357	428	543	511	626

[a]Includes agriculture (livestock and crops), sand and gravel mining, construction, transportation, communications and public utilities, agricultural processing and miscellaneous manufacturing, finance-insurance-real estate, business and personal service, professional and social service, government, coal mining, electric generation, petroleum exploration/extraction, and petroleum refining.

finance-insurance-real estate, business and personal service, and household sectors. The largest annual expenditure would accrue to the retail sector and would range from $47,000 for the small, at-site facility to $251,000 for the large, central storage and distribution facility (Table 18).

The economic impact of the pelleting facilities during the operational phase would be an increase in gross business volume of $322,000 for the small, at-site facility to $1,024,000 for the large, central storage and distribution facility annually in the local region (Table 19). The retail trade and household sectors of the economy realize the largest increase in the level of business activity. Permanent employment at the facilities would range from three to six. Increase in the level of business activity resulting from the operation of the pelleting facilities would provide jobs for two, three, seven, five, and eleven indirect workers for the small, medium, and large at-site facilities and the medium and large central storage and distribution facilities, respectively. These local economic impacts of operating a pelleting facility would occur annually as long as the facility is operational.

TABLE 18. LOCAL EXPENDITURES BY ECONOMIC SECTOR RESULTING FROM OPERATION OF FLAX SHIVE PELLETING FACILITIES, NORTH DAKOTA, 1981

Sector	Plant Size and Type				
	At Site			Central	
	Small	Medium	Large	Medium	Large
	$000				
Retail	47	82	155	145	251
Finance, Insurance, and Real Estate	26	35	51	43	57
Business and Personal Service	3	4	6	4	6
Households	39	44	63	66	89
Total	115	165	275	258	403

TABLE 19. ADDITIONAL GROSS BUSINESS VOLUMES OF ECONOMIC SECTORS RESULTING FROM THE OPERATION OF FLAX SHIVE PELLETING FACILITIES, NORTH DAKOTA, 1981

Resulting Increase in Gross Business Volume by Sector	Plant Size and Type				
	At Site			Central	
	Small	Medium	Large	Medium	Large
	$000				
Retail	108	163	281	265	428
Household	113	146	226	215	312
Other[a]	101	137	214	195	284
Total	322	446	721	675	1,024

[a]Includes agriculture (livestock and crops), sand and gravel mining, construction, transportation, communications and public utilities, agricultural processing and miscellaneous manufacturing, finance-insurance-real estate, business and personal service, professional and social service, government, coal mining, electric generation, petroleum exploration/extraction, and petroleum refining.

Environmental Impact of Producing and Burning Flax Shive Pellets

The environmental impact of producing flax shive pellets is negligible, with the main source of pollution originating from the diesel engines. Flax shive is considered a waste product by cigarette paper manufacturers and, therefore, the pelleting procedure would benefit the surrounding area's environmental condition by utilizing the shive. Some erosion caused by straw removal would occur regardless of whether the shive was processed or left in a depository, since flax shive is a by-product material. Direct combustion and gasification of flax shive were found to have a significantly less environmental impact than coal or other petroleum fuels. However, biomass may still produce human health and environmental problems, according to biomass pollution studies. Air emissions from biomass include particulates; oxides of nitrogen, sulfur, and carbon; hydrogen cyanide; ammonia; and hydrocarbons.[9] Impacts related to burning biomass were determined to be similar but less severe than burning coal. However, most knowledge about biomass pollution has been directed towards forest-related fuels and not crop residue. Studies directly related to the emissions from burning flax shive pellets are limited. Dakota Pelleting Corporation of Watertown, South Dakota, has compiled selected data on the chemical composition of flax shive pellets. Chemical composition of air-dried and moisture-free flax shive pellets are presented in Table 20. Flax shive pellets were found to produce less visible pollution in the form of smoke. Only small white puffs of smoke, which was mostly water vapor, were given off when flax shive pellets were burned in various South Dakota schools.[10]

Summary and Conclusions

Summary

Commercial and seed flax are the two types of flax grown in the United States. Commercial flax is grown primarily for its fiber and is used in the

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[9] U.S. Department of Energy, Environmental Readiness Document, Biomass Energy Systems, DOE/ERD-0021, Washington, D.C., September 1979, page 5.

[10] Burg, Bette, "Coal Bins Filled With Flax Pellets at Woonsocket School," Plainsman Huron Daily, Huron, South Dakota, October 1, 1978, page 13.

TABLE 20. CHEMICAL COMPOSITION OF FLAX SHIVE PELLETS

Chemical	Air-Dried	Moisture-Free
	--------Percent--------	
Approximate		
Moisture	7.29	0.00
Volatile Material	71.21	76.81
Fixed Carbon	18.07	19.49
Ash	3.43	3.70
Ultimate		
Hydrogen	6.01	5.61
Carbon	43.81	47.25
Nitrogen	0.60	0.65
Oxygen	45.36	41.94
Sulfur	0.78	0.84
Ash	3.43	3.70
Chlorine	0.012	0.013
BTU per pound	7,636	8,236
Weight 35#-40# C.V.F.		

SOURCE: Communication with personnel from Dakota Pelleting Corporation, Rauville Plant, Watertown, South Dakota.

manufacture of linens. Seed flax, grown principally for its seed, is produced in relatively large quantities in North Dakota. North Dakota continues to harvest the largest number of flax acres in the United States, although its flax acreage has declined from 1,644,000 acres in 1970 to 310,000 acres in 1980.

Flax straw fiber is the primary material used in the production of cigarette and other fine textured papers. The fiber is obtained through a decortication process which breaks the flax stem into shive and tow. Flax straw is collected from the field and decorticated into flax tow, which contains 50 percent fiber and 50 percent shive. The tow is then shipped to cigarette paper manufacturing companies for further processing. Flax shive, the woody portion of the stem, is considered a waste product by cigarette paper manufacturers.

Schweitzer, a division of the Kimberly-Clark Corporation, and Olin Corporation are the only two companies in the United States that process flax straw into cigarette paper. These two firms process 95 percent of the domestic cigarette paper requirements and are vertically integrated from collecting straw to the manufacturing of cigarette paper. The possibility of another flax tow producing company successfully entering the tow market and competing with these two firms is unlikely.

Flax shive, a by-product of flax tow production, has potential for use as an alternative energy source. Several businesses and institutions either have or are utilizing flax straw and/or shive as a supplemental fuel source. One firm currently produces flax shive pellets in the United States.

Pelletization was considered the most convenient method for transporting and burning of flax shive due to its relatively high density and low bulk. Model plant costs were estimated for a portable unit capable of processing at various decortication sites throughout northeastern and north central North Dakota. Costs were computed for both "at" and "central" storage and distribution sites.

The market potential for flax shive pellets was determined by analyzing present utilization, various burner systems and cost of alternative fuels. The economic impact of flax shive processing facilities on the economy of North Dakota were computed using capital investment and operating cost estimates. The environmental considerations associated with the production and utilization of flax shive pellets also were addressed.

Conclusions

North Dakota leads the nation in the production of flax and flax straw. This trend is expected to continue although acreage is expected to decline to 214,000 acres by 1990. Flax shive will remain in sufficient quantities through 1990 to maintain even the largest flax shive pelleting facility at 100 percent capacity.

Model plant construction and operating costs were estimated for three plant sizes (2,080, 10,400, and 20,800 tons annually) and two storage and distribution methods (at-site and central storage and distribution). Total investment costs for the at-site distribution method were $244,721, $326,515, and $447,471 for the small, medium, and large facilities, respectively. Annual operating costs for these same plants were $161,491, $321,802, and $573,667. Capital investment for the medium and large, central storage and distribution facilities were $412,136 and $533,092. Annual operating costs for these two facilities were estimated at $422,520 and $711,307.

Revenue estimates were calculated for the model plants at break-even prices plus a 15 percent return on investment. Revenue estimates were computed at $95.29, $35.65, and $30.81 per ton of output for the small, medium, and large, at-site facilities and $46.57 and $38.04 per ton of output for the medium and large, central storage and distribution facilities. Although the cost of using coal as a heat source would be minimally less than that of pellets, all sized facilities could effectively compete on a cost per BTU basis with propane, electricity, and fuel oil.

Economic impacts of potential flax shive pelleting facilities will accrue during the construction and operational phase. Impacts from the construction phase range from $357,000 to $626,000 while operational impacts range from $322,000 to $1,024,000.

Furnaces are available that burn flax pellets or lignite coal very efficiently and with little maintenance. Flax pellets also may be gasified and used as a substitute for natural gas with only minor adjustments to present gas furnaces. Flax shive pellets burn clean with little smoke being produced. Although lignite coal may cost less than pellets, the advantages of cleaner burning with less dust and odors in handling may make burning flax shive pellets attractive.

Selected References

Burg, Bette, "Coal Bins Filled With Flax Pellets At Woonsocket School," Plainsman Huron Daily, Huron, South Dakota, October 1, 1978.

Desrosiers, Raymond E., Process Designs and Cost Estimates For A Medium BTU Gasification Plant Using A Wood Feedstock, SERI/TR-33-151, Solar Energy Research Institute, Golden, Colorado, February 1979.

Goldeborough, G., Seed Flax Straw, Potential For Extending Its Utilization, Agriculture Research Service, U.S. Department of Agriculture, April 1963.

Hauffe, Rick, "Heating With Flax Goes Back For Many A Year," Watertown Public Opinion, February 6, 1979.

Lindley, J. A., L. J. Roehl, and M. Vossoughi, Processing Residues For Us As An Energy Source, Agricultural Engineering Department, North Dakota State University, Fargo, 1980.

Minnesota Agricultural Statistics Service, Minnesota Agricultural Statistics, 1977, 1978, 1979, 1980, 1981, Minnesota Department of Agriculture, St. Paul, Minnesota.

North Dakota Crop and Livestock Reporting Service, North Dakota Agricultural Statistics, 1980, 1981, Ag Statistics Nos. 45 and 48, Fargo, North Dakota, 1976-1981.

_______, North Dakota Crop and Livestock Statistics, Ag Statistics No. 42 and 44, Fargo, North Dakota.

Overand, Ralph, Gasification -An Overview, Retrofit 79, "Proceedings Of A Workshop On Air Gasification," SERI/TP-49-183, Solar Energy Research Institute, Seattle, Washington, February 1979.

Smetanka, Mary J., "Warroad Firm Taking Advantage Of Cheap Fuel Substitutes For Heat," Grand Forks Herald, April 26, 1981.

South Dakota Crop and Livestock Reporting Service, South Dakota Historic and Livestock Estimates 1976-1980, Sioux Falls, South Dakota, July 1981.

Torkelson, David R., North Dakota Industrial Location Facts, North Dakota Economic Development Commission, Bismarck, North Dakota, July 1981.

U.S. Department of Agriculture Statistical Reporting Service, Crop Production Annual Summaries, 1972-1981, CrPr 2-1 (72-81), Washington, D.C.

U.S. Department of Energy, Environmental Readiness Document, Biomass Energy Systems, DOE/ERD-0021, Washington, D.C., September 1979.

Zuk, Bernie, Industrial Services Division, Saskatchewan Research Council, Saskatoon, Saskatchewan.