PRAIRIE
PRACTITIONERS
GROUP

Final Report

Straw Procurement Business Case

Submitted to
Manitoba BioProducts Working Group
c/o Eric Liu

Submitted by
Prairie Practitioners Group Ltd.
In association with
The Composites Innovation Centre

March 31, 2008

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Acknowledgements

Prairie Practitioners Group Ltd. would like to thank Manitoba Agriculture, Food and Rural Initiatives (MAFRI), Competitiveness, Training and Trade (CTT) and Science, Technology, Energy and Mines (STEM) for their support of this Study. We would also like to thank the Project Steering Committee, the Bio-Products Advisory Working Group and the Composite Innovations Centre for their input and advice. A special thank-you is extended to all the producers, custom operators, extension, research and other industry people who provided valuable in-sight.

Executive Summary

This Study explores the economic case for establishing a procurement system to supply crop residues to prospective commercial or industrial users and develops a business case which can be utilized for investment attraction.

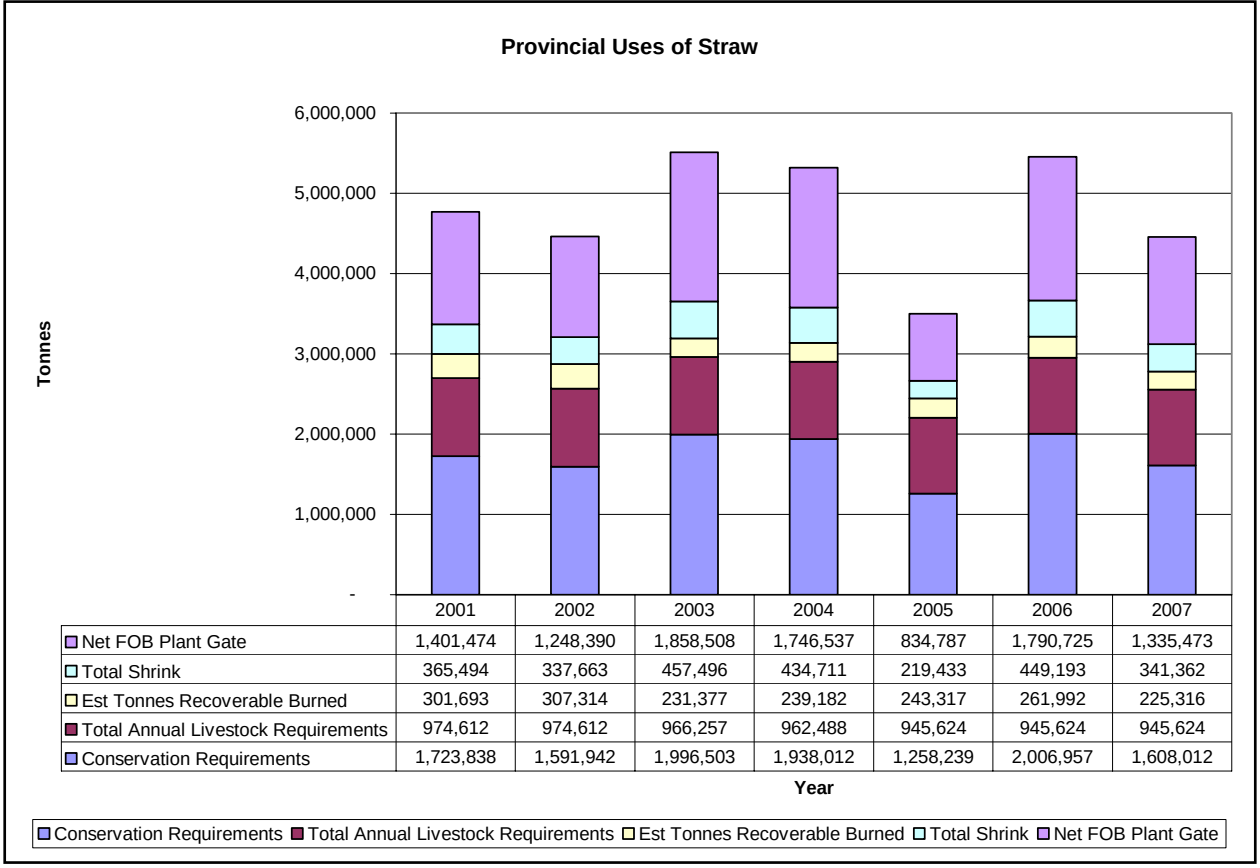
The crop residues of interest in this Study include straw from wheat, winter wheat, barley, oats, rye, flax and corn stover.

The methodology used in completing this Study included:

- A review of research literature in the field of fibre production, fibre processing and the management of logistics systems in North America and Europe.
- Compiling production and other forms of statistical data on production and processing.
- Primary research including key informant interviews, focus groups and surveys with producers and custom operators.
- Further development and refinement of the logistics and costing model. This logistics and costing model was run with three different scenarios.
- On-going liaison with the project advisors to obtain input.

This report begins by providing a province-wide analysis breakdown of the types and amounts of straw produced in Manitoba in an average year. The production supply model allows user defined input on the basis of area (Rural Municipality by Rural Municipality), yield, amount needed for conservation, livestock use and percent recoverable. For the example in this report the production supply model uses typical straw to grain ratios (i.e. 1.3 wheat), soil conservation needs at 750 kg/ha and livestock needs at 5 kg/head/day.

The following chart illustrates the provincial use of wheat straw for the years 2001 – 2007.



	2001	2002	2003	2004	2005	2006	2007
Net FOB Plant Gate	1,401,474	1,248,390	1,858,508	1,746,537	834,787	1,790,725	1,335,473
Total Shrink	365,494	337,663	457,496	434,711	219,433	449,193	341,362
Est Tonnes Recoverable Burned	301,693	307,314	231,377	239,182	243,317	261,992	225,316
Total Annual Livestock Requirements	974,612	974,612	966,257	962,488	945,624	945,624	945,624
Conservation Requirements	1,723,838	1,591,942	1,996,503	1,938,012	1,258,239	2,006,957	1,608,012

Following on the provincial breakdown the Study provides an analysis of Manitoba vs. Saskatchewan and Alberta. This is then followed by a provincial breakdown of current uses of straw including processing, livestock use, soil incorporation, and straw burning. For each of these uses a descriptive analysis is provided illustrating factors considered in arriving at appropriate levels of use.

The Study goes on to identify current and potential fibre processing markets for the different types of straw produced within Manitoba**.** For each of these uses a description is included along with a preliminary indication of need to investigate further in Manitoba. The current and potential uses include:

- Utilization of Straw in producing Erosion Control Material
- Utilization of Straw for Heat and Power
- Densification of Straw to produce Pellets, Cubes, Briquettes and other Products
- Utilization of Straw in Composite Materials
- Utilization of Straw for Pulp and Paper Production
- Cellulose from Straw in Producing Ethanol/Biofuels
- Biomass to Bio-oil by Pyrolysis
- Utilization of Straw for Chemical feedstocks & bio-refineries

Based on information compiled and input from the Study Advisory Committee the following fibres of focus and preliminary business scenarios were identified:

- Biomass to Heat and Power (Cereals, Corn Stover and Flax Shives)
- Flax Fibre for Industrial Uses (Flax)
- Potential Large scale user – cellulose to ethanol (Cereals, Corn Stover)

The next section includes an assessment of the quality needs for each of the above scenarios along with a preliminary indication of availability of straw that would meet

these quality needs. Building on these quality factors the Study then addresses factors such as storage, harvesting and baling and provides input on producer attitudes and willingness to alter harvesting and baling practices in order to provide straw to a business.

An important factor when considering straw availability is the value of the straw to the producer. The Study provides an analysis of the farmer treating straw as a valuable resource.

Section 4.2 provides an analysis of factors such as possible uses of waste straw, alternative uses of excess straw, spoilage and shrinkage. This part of the report also provides an overview of straw combustion and gasification technology and the various burners/boilers available.

In section 4.3 the Report provides a detailed analysis of a number of areas which include:

- An in-depth analysis of the cost of baling
- A cost analysis template that can be used for the analysis of a straw procurement operation of any size
- A productivity analysis which takes into account changing weather and crop production variables
- Determining the cash flow requirements for a seasonal baling business
- Financing options for storage and purchase of fibre and payment models
- A cost comparison of using 4x4x8 large square bales vs. large round bales
- An evaluation of alternative handling methods other than baling
- A costing analysis which includes purchasing/leasing equipment vs. hiring out as custom work
- A costing of transportation for a 50 and 75 mile radius of main storage site**.**
- An analysis of storage options
- An analysis of straw purchase models
- An environmental cost/benefit analysis

The logistics and costing analysis model allows user defined input in all the key areas of input thus enabling a prospective business to analyze many different options. The example in the following table illustrates how the Costing and Logistics Model enables the user to compare the relative cost of using four different baling systems, namely, large round bales, medium cube bales, large cube bales and very large cube bales. In this example there is a clear relationship between the level of capital intensity (i.e. capital cost of equipment) and decreasing cost per tonne.

Comparison of Logistics Costs		
Harvesting Method	Baling Costs (per tonne)	Cost FOB Plant Gate (per tonne)
Large Round Bale	$12.68	$41.28
Medium Cube Bale	$10.01	$35.49
Large Cube Bale	$7.68	$31.68
Very Large Cube Bale	$6.77	$27.81

Section 4.3 concludes with an overview of regulatory considerations with regard to fire prevention, rodent control and road/transport restrictions.

In the concluding Section 5.0, for each of the Business Case Scenarios, the Study provides a brief description, an indication of the size and the logistics footprint, a description of the type of bales used and the feedstock procurement system. For each scenario a chart is included providing an illustrative example of the logistics costs associated with this type of processing operation.

1.0 Introduction

This Report provides the results of a Study into a "Straw Procurement Business Case". This Study was completed by Prairie Practitioners Group Ltd., in association with the Composite Innovations Centre, for Manitoba Agriculture, Food and Rural Initiatives (MAFRI), Competitiveness, Training and Trade (CTT) and Science, Technology, Energy and Mines (STEM).

The overall purpose of the Study was to explore the economic case for establishing a procurement system to supply crop residues to prospective commercial or industrial users and to develop a business case which could be utilized for investment attraction.

The methodology used in completing this Study included:

- A review of research literature in the field of fibre production, fibre processing and the management of logistics systems in North America and Europe. The report for this segment of the Study is referred to as "Secondary Information Review" and included as Appendix 1.
- Compiling production and other forms of statistical data on production and processing.
- Primary research including key informant interviews, focus groups and surveys with producers and custom operators.
- Development and refinement of a logistics and costing model and;
- On-going liaison with the project advisors to obtain input.

This report is divided into a number of sections.

- For project reporting continuity, Section 2.0 ***Background*** and Section 3.0 ***Approach and Methodology*** are included as they appeared in the initial Project Initiation Report.
- Section 4.0 of the report addresses each of the study components which were specified in the Terms of Reference.
- Section 5.0 provides an overview of each of the three Business Case Scenarios including type of operation, size, straw procurement systems and a chart providing an illustrative example of the logistics costs associated with this type of processing operation.
- Section 6.0 highlights some overall observations and recommendations (This Section of the Report will be developed following further consultations with the Project Advisory Committee).

2.0 Background

2.1 Purpose of the Study

The purpose of the study is to explore the economic case for establishing a procurement system to supply crop residues to prospective commercial or industrial users and to develop a business case which could be utilized for investment attraction.

2.2 Our Understanding of the Sector

Over the last 15 to 20 years, a considerable amount of time has been invested in Manitoba and other jurisdictions to research, develop and operate ventures that can covert agriculture fibre materials into novel products. The scope of this effort has ranged from small-scale residential, farm or commercial heating system to larges-scale (800,000 tonnes per year) fibre-to-ethanol production ventures.

Some processing ventures, such as converting flax straw into paper and fibre input-materials are well established, while other can be considered to still be in the research and development stage of establishment.

Overall, there is a broad range of current and potential uses for ag fibre materials. For example in Manitoba, ag fibre materials are currently being used or have been used as feedstock materials for:

- providing nutrients into crop production systems (either directly or via composting)
- the livestock production sector (feed and bedding)
- space heating applications at farm and commercial locations
- fine paper production
- woven mat construction
- straw-board manufacturing

A quick scan of the situation in other jurisdictions and the research literature indicates we have only begun the process of utilizing ag fibre. For example:

- in Northern Europe, several hundred thousand tonnes of ag residue materials are used to produce energy for utilities and community-based combined heat and power systems
- also in Northern Europe, ag residues are used as a feedstock material in bio-gas production systems that produce heat and electrical power
- a broad range of opportunities have been identified to supply natural fibre products to the automotive manufacturing and other industries (e.g. http://www.newuses.org/about.php)
- a number of firms and a significant level of government research investment has been devoted to commercializing technologies to convert ag residues and other fibre products into ethanol and other liquid or gas fuels (e.g. http://www1.eere.energy.gov/biomass/publications.html)
- research and development continues in the bio-composites area that focuses on producing a broad range of novel construction product inputs for the green building / green design sector (e.g. http://www.crossroadbiotech.ca/program_e.html; http://www.bc.bangor.ac.uk/_03_research/research5_composites.htm).

The potential size of processing ventures varies considerably. For example, a residential or commercial scale biomass heating system may only require 100 tonnes of feedstock per year. At the other extreme, large scale paper processing or biomass ethanol production enterprises may require a supply of feedstock materials exceeding 800,000 tonnes per year. In between these two extremes would be pellet fuel production ventures that could require 20,000 tonnes of feedstock per year, flax straw processing systems that may require 20,000 to 100,000 tonnes of feedstock per year, or large-scale straw board plants that may require 100,000 to 300,000 tonnes of feedstock materials per year.

While the cost of production of ag fibre, and in particular ag residue materials, in Manitoba is quite competitive to other jurisdictions, this is only one small element of the cost drivers one needs to consider. In most situations, the cost of the harvesting and logistics management of the feedstock is a much larger cost than the cost of the raw product. Accordingly, anyone hoping to attract investment in ag fibre processing ventures must pay close attention to this issue if the venture in question is to be successful.

Within this context, it is important to learn from established business and operating models that have emerged in the forage, hemp and flax straw processing sectors. There is a wealth of experience and knowledge to be gained by reviewing how these sectors manage their harvesting and logistic operations with an eye to understanding how these models can be adapted for the needs of other processors.

It is also important to consider alternative uses for input feedstock materials, co-products, and waste products. Each type of processing venture has unique input quality control needs for feedstock materials, as well as unique co-products and waste material product streams. It is critical to identify a means to treat these materials as inputs to other processes instead of as waste products that increase the cost of operations due to paying for disposal costs.

Within this context, it is timely to undertake a study that will examine how Manitoba can be positioned to attract investment in viable and sustainable ag fibre processing ventures. We understand that the focus of this initial study is to concentrate on ag residue materials such as grain straw and flax straw. However, it is quite possible that future research may extend this investigation into other ag fibre materials such a hemp fibre, forage products, and dedicated energy crop such as switchgrass, hybrid poplar trees, and fast growing shrubs such as willows.

2.3 Our Overall Approach to the Research

Our project team appreciates the fact that the topic of this study is not a new field of business in Manitoba. There are established business operations throughout the province that can provide key insights into how to scale up our production and processing capabilities to meet their full potential.

Accordingly, we will approach this research by first conducting a thorough scan of the experience in Manitoba and other jurisdictions using a combination of secondary and primary research methodologies. This approach will be supplemented with a "participatory research and planning methodology" that engages current operators in a review, analysis and interpretation of this initial research. While we respect the value of academic research in this area, we believe the most valuable expertise resides with the people who are already operating ventures that either are or one day will become part of the value chain systems in this sector. Like most agriculture-related ventures, there is a wealth of experience and innovative ideas that exist in the field and it is essential to tap into this resource if we are to advance Manitoba's development objectives in this sector.

3.0 Approach and Methodology

In the following points our consulting team has outlined the methodology for completing the study. This methodology has been reviewed with the Project Steering Committee and they have agreed on the methods being used. Given the nature of the topic being studied we also recognized that it might have been necessary during the course of the study to alter the methodologies that are being used, in order to obtain that best possible information and analysis. Any changes to the methodologies will be agreed upon with the Project Steering Committee.

3.1 Project Steering Committee – the Province of Manitoba Bio-Products Working Group served as the Project Steering Committee and provided overall direction and guidance for the study. The Consulting team met with this Project Steering Committee upon completion of each of the progress reports.

3.2 Bio-Products Advisory Working Group – the Bio-Products Advisory Working Group included the following individuals: Eric Liu, MAFRI; Tracy Gilson, MAFRI and Dan Caron, MAFRI. This Bio-Products Advisory Working Group provided the consulting team with on-going advice as the study proceeded.

3.3 General literature review – this included a general internet search of news articles, press releases, and other information sources pertaining to fibre processing ventures and the management of logistics systems in North America and Europe.

3.4 Review of research literature in the field of fibre production, fibre processing and the management of logistics systems in North America and Europe – this included accessing and reviewing published articles and reports from the research community in these fields.

3.5 Accessing production and other forms of statistical data on production and processing – this included accessing information from sources such as: Manitoba Management Plus; Statistics Canada; Agriculture Canada and Natural Resources Canada.

3.6 Primary research – from the above three areas of secondary research a preliminary review and analysis was completed. During the course of this review key informants were identified. Primary research was then conducted using the following methodologies:

3.6.1 Key informant interviews - key informant interviews were utilized to obtain information on several components of the study. Individuals were selected who were knowledgeable in the area being studied. These individuals were interviewed utilizing a specific list of questions for the area being studied. The list of key informants was expanded as the study proceeded.

3.6.2 **Focus groups** – in a number of components of this study an interactive focus group process was utilized. The focus groups involved key individuals in helping to further analyze the topic being considered. The consulting team conducted one focus group with each of the following areas:

- Producer willingness to change and improve operations for straw quality, attitudes re: straw use (agricultural producers, ag extension personnel, ag sector researchers)
- Cost of straw purchase, baling, stacking, transportation, storage (custom operators, ag extension personnel, ag sector researchers)

3.6.3 Surveys

3.6.3.1

Qualitative (exploratory research approach) surveys were utilized in a number of components of this study. For example qualitative methods will be used to identify and/or develop quality parameters for each end use of the fibre.

3.6.3.2

Quantitative (descriptive research approach) surveys were utilized in the following areas:

- **Survey of custom operators –** a survey of custom operators was conducted to assemble information on the cost and logistics of straw purchase, baling, stacking, transportation and storage.
- **Survey of Producers**

  As outlined in 4.6.3.1 of the proposal, a survey of producers was conducted to gather information on the following topics:
  - current use of straw and producer intentions regarding possible future use of straw;
  - producer opinions regarding the value of straw;
  - potential equipment modifications for straw procurement:
  - producer opinions on various options for baling, stacking, storage, transportation and financing models.

To obtain this information a questionnaire was developed and distributed to at least 200 agricultural producers throughout agro-Manitoba. Directors of Keystone Agricultural Producers (KAP) were the producers who were surveyed.

KAP is a democratically controlled general farm lobby organization which represents and promotes the interests of agriculture and agricultural producers in Manitoba. It is a grassroots organization wholly run and funded by its members, with all policy set by producers throughout Manitoba. Policy is set by delegates and directors elected from individual and commodity group members. Close to twenty committees, comprised of members and the President (ex officio), research relevant issues and report back to the executive and the General Council. For further information on KAP please see http://www.kap.mb.ca.

The details of our methodology included the following:

- Development of the survey questionnaire
- Testing of the questionnaire with at least four producers
- Preparation of a list of producers using:

- a total of 144 KAP district directors (12 from each of the 12 districts) – please see the map below (obtained from http://www.kap.mb.ca/districts.html) showing the geographical distribution of the districts
- a total of 84 KAP group directors (4 from each of 21 groups)
- Distributing the questionnaire by e-mail or fax
- Telephone follow-up with each person to whom the questionnaire was distributed but not returned
- Compilation of results
- Summarizing of results

(Note: Young Farmers - Please note that the district directors include the eight members of the Young Farmers Co

4.0 Study Components

This section of the report addresses each of the study components which were specified in the Terms of Reference. The information collected and the analyses developed were supported by the responses provided through the interviews, surveys and focus groups and supplemented by the information obtained through the Secondary Information Review.

4.1.1 Gather information on the types and amounts of straw produced within Manitoba in an average year, including breakdowns for different areas of the province.

4.1.1.1 Province-Wide Analysis

The consulting team compiled information about the amount of grain produced in the period extending from 2001-2007 from the Management Plus Service of Manitoba Agricultural Services Corporation http://www.masc.mb.ca/mmpp.nsf/Home_Page.html?OpenPage .

The data was extracted at both a Rural Municipality and a Risk Territory-level of resolution. In addition, each RM data set was assigned a census region and census area code to enable sorting and analysis of production data according to Census definitions of regions.

A straw-to-grain ratio was estimated for each type of crop based on the analysis that was done in Section 4.1.1 of the Secondary Information Report. The following chart illustrates the straw to grain ratios for the straw being considered in this Study. Based on information from the literature review; lower limits, upper limits and, where possible, typical ratios are indicated.

Straw to Grain Ratio			
Crop	Lower Limit	Typical Ratio	Upper Limit
Wheat	1.3:1		1.7:1
Winter wheat	1.7:1[1]		?
Barley	1:1		1.4:1
Oat	1:1		1.4:1
Rye		1:1	
Flax (straw yield)		1.2:1[2] 1.235 tonne/ha[3]	
	1.18:1		1.25:1[6]
Flax fibre		1.0 tonne/ha average[4] Generally in the range	

[1] Nelson RG, Walsh M, Sheehan JJ & Graham R "Methodology for Estimating Removable Quantities of Agricultural Residues for bioenergy and Bioproduct Use" Report in Applied Biochemistry and Biotechnology Vol. 113-116

yield	of 15 – 20%.[5]
Corn	1:1[7]

In assessing the amount of crop residues that are available for alternative uses there seems to be general agreement that "biomass considered be available in environmentally sustainable economic quantities" [8] In other words the impact on soil erosion and the impact on soil nutrients along with the economics of utilizing the crop residues are elements that must be taken into consideration in assessing how much residue can be removed.

Work done by PAMI in Saskatchewan indicate that "relationships exist that can be used to predict straw yield based on rainfall, straw type, straw height and cutting height" [9] PAMI 2001 reported on the research which studied "how any factors such as variety, location and moisture affect straw to grain ratios" [10] Tables 1, 2, 3 & 4 in the Secondary Information Review (Appendix 1) show the results of this PAMI 2001 research. The straw is the total mass other than grain with the straw cut at ground level and including chaff. The amount of straw is also determined at 0% moisture content. The following table provides the study results indicating the average S/G ratio by location. These results indicate a definite relationship between S/G ratios and the location in the province.

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[2] Tillage practices that reduce soil erosion Report By AAFC available at: http://www.agr.gc.ca/pfra/soil/tillage_e.htm

[3] Amount estimated in study "The Nutrient Loss of Straw Removal or Burning in Manitoba" by Heard J, Cavers C and Adrian G. Manitoba Agriiculture and Food 2001 Available from: http://www.umanitoba.ca/afs/agronomists_conf/2001/pdf/heard2.pdf

[4] Email from Scott Duguid, AAFC, Morden

[5] Email from Scott Duguid, AAFC, Morden

[6] Conversation with Joe Hogue (Schweitzer-Mauduit) on straw yields and using average flaxseed yields.

[7] Towards A Technology Roadmap for Canadian Forest Biorefineries Available from: http://strategis.ic.gc.ca/epic/site/lsg-pdsv.nsf/vwapj/Biorefineries-eng.pdf/$FILE/Biorefineries-eng.pdf

[8] Stumborg, Mark P.Eng. and Townley-Smith, Lawrence Ph.D "Agricultural Biomass Resources in Canada" Written for presentation at the 2004 ASAE/CSAE Annual International Meeting Sponsored by ASAE/CSAE Ottawa, Ontario, Canada 1 - 4 August 2004

[9] Lischynski, D, Hill, L. and Boyden, A. "Wheat Straw Availability and Quality Changes During Harvest, Collection and Storage" Prairie Agricultural Machinery Institute, P.O. Box 1150, Humboldt, Sask. S0K 2A0 Canada

[10] Final report on Reliable Data on Sustainable Wheat Straw Availability – Straw Production, Prairie Agricultural Machinery Institute Study available from Brenda Freistadt Secretary, Western Beef Development Centre & Communications Assistant, PAMI bfreistadt@pami.ca

Average S/G Ratio by Location

Location	S/G Ratio
Melfort	1.4
North Battleford	1.1
Kindersley	1.0
Yorkton	1.5
Swift Current	1.2
Indian Head	1.5

In the production supply model, this Straw to Grain ratio has been assigned as a user-defined input to the model. For this report, the following ratios have been employed:

- wheat – 1.3 tonnes of biomass per tonne of grain
- all other crops – 1.1 tonnes of biomass per tonne of grain

It should be emphasized that the straw to grain ratio may vary considerably from one area of Manitoba to another and from one year to another. While the ratio of 1.3 is used for this Study, the production supply model allows for user-defined input in this area.

To arrive at the amount of recoverable straw, the total production of biomass was reduced to a level that would represent harvesting losses and biomass remaining in the stubble. In this report, it has been assumed that 63% of total biomass production may be available for harvesting. Again, this is a user-defined input variable for the model.

Soil conservation requirements were determined by assuming that 750 lb/acre of biomass needs to be returned to the soil (this is also a user-defined input variable **and in this Study we are assuming that a range of 750 kg/ha to 1 tonne/ha would be adequate).** The model compares this conservation need to the amount of biomass contained in the stubble and returns a maximum allowable amount available for harvesting while still meeting soil conservation needs.

Livestock needs are discussed in more detail in Section 4.1.3 of this report. In the straw production model, livestock production needs have been broken out to an RM or Risk Territory Level of resolution.

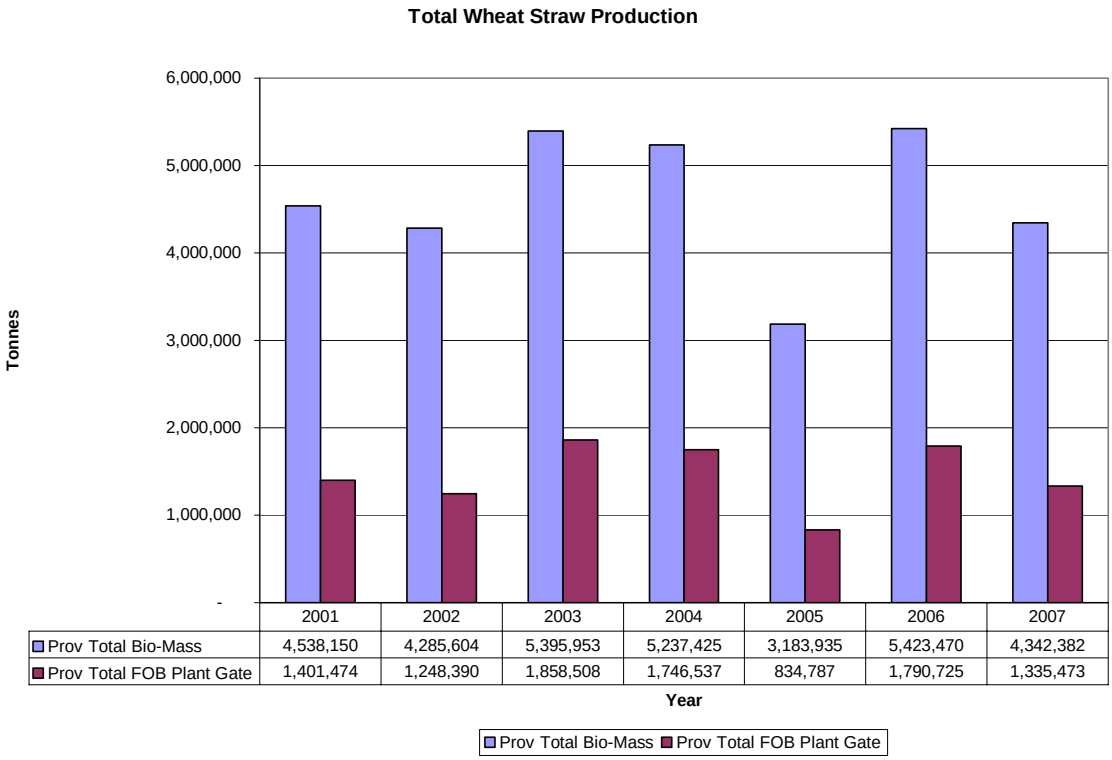
An estimation of spoilage and shrinkage is included in the model. The user of the model can define field, handling, and storage shrinkage factors. For this report, it has been assumed that:

- field loss is 3% of recoverable straw
- handling loss is 5% of recoverable straw
- storage loss is 10% of recoverable straw (i.e. assuming non-covered storage).

Finally, the model provides an estimate of the amount of straw removed by burning across the province. The determination of this estimate is explained in more detail in Section 4.1.3 of this report. On a province-wide basis, it is estimated that about 300,000 tonnes of recoverable straw/biomass is currently removed by burning.

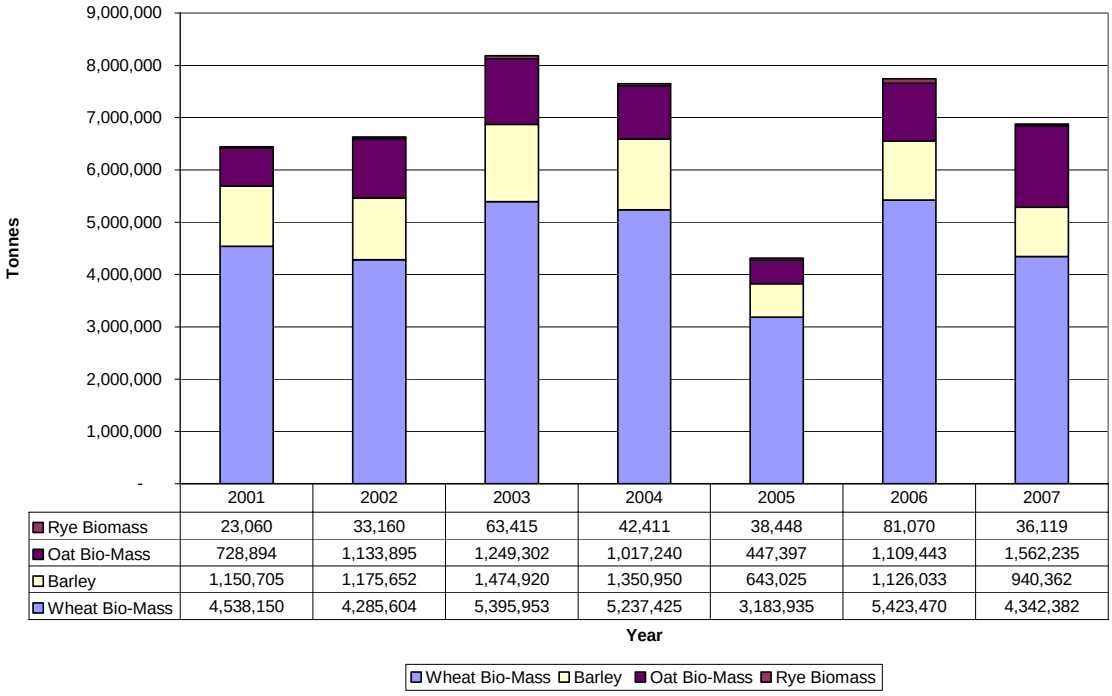
It is important to note that the amount of straw which will be made available to a business will depend upon producers' operational plans and the financial consideration offered.

The following two charts provide a graphical summary of the amount of cereal straw bio-mass produced and available for harvesting during the period extending from 2001 – 2007.



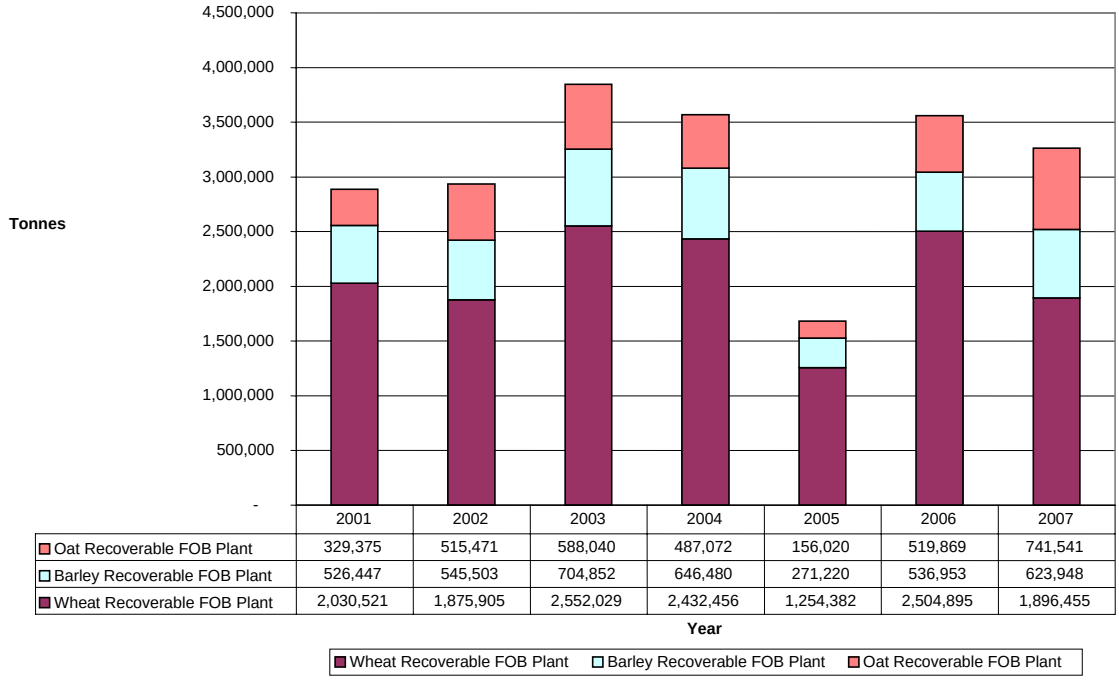
	2001	2002	2003	2004	2005	2006	2007
Prov Total Bio-Mass	4,538,150	4,285,604	5,395,953	5,237,425	3,183,935	5,423,470	4,342,382
Prov Total FOB Plant Gate	1,401,474	1,248,390	1,858,508	1,746,537	834,787	1,790,725	1,335,473

Total Cereal Grains Bio-Mass



	2001	2002	2003	2004	2005	2006	2007
Rye Biomass	23,060	33,160	63,415	42,411	38,448	81,070	36,119
Oat Bio-Mass	728,894	1,133,895	1,249,302	1,017,240	447,397	1,109,443	1,562,235
Barley	1,150,705	1,175,652	1,474,920	1,350,950	643,025	1,126,033	940,362
Wheat Bio-Mass	4,538,150	4,285,604	5,395,953	5,237,425	3,183,935	5,423,470	4,342,382

Prov. Cereal Straw Recoverable

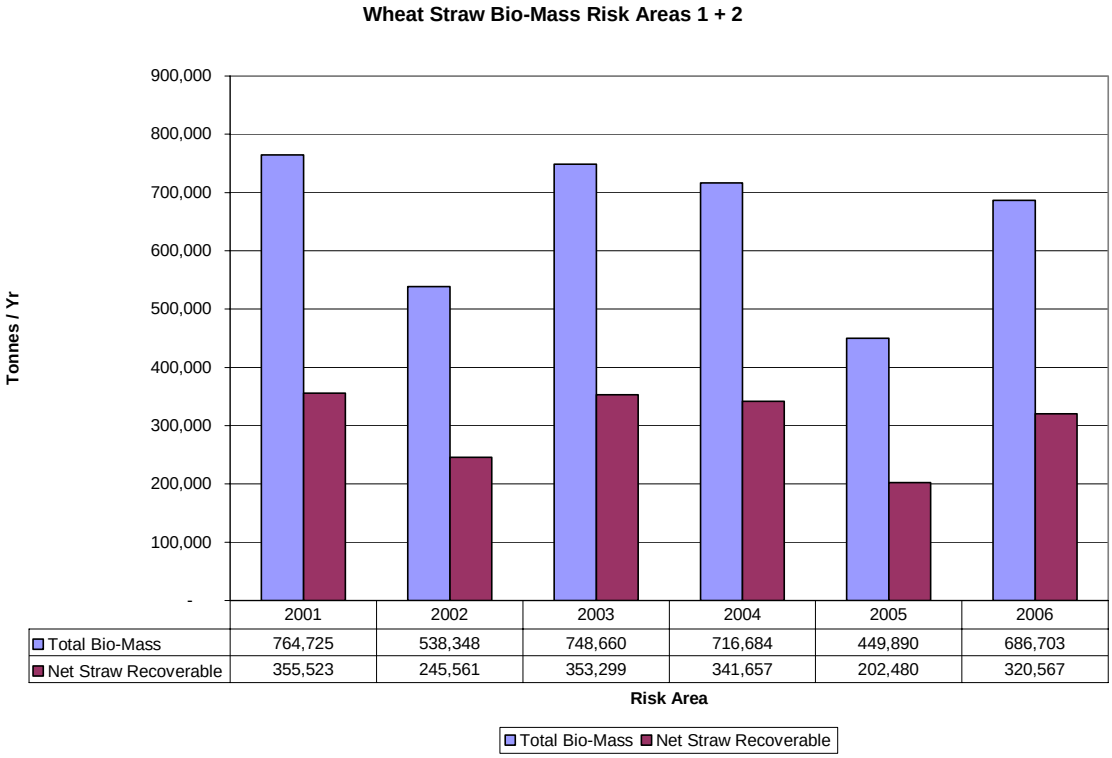


	2001	2002	2003	2004	2005	2006	2007
Oat Recoverable FOB Plant	329,375	515,471	588,040	487,072	156,020	519,869	741,541
Barley Recoverable FOB Plant	526,447	545,503	704,852	646,480	271,220	536,953	623,948
Wheat Recoverable FOB Plant	2,030,521	1,875,905	2,552,029	2,432,456	1,254,382	2,504,895	1,896,455

4.1.1.2 Regional Breakdown of the Data

The model enables the user to extract production data according to MASC Risk Territories, Census Territories or Census Areas. The model also estimates the livestock production requirements by MASC Risk Territory in addition to an RM-level of data analysis.

The number of permutations and combinations of these areas can be defined by the user according to their specific need. The following chart presents an illustrative example of this capability for MASC Risk Areas one and two.



	2001	2002	2003	2004	2005	2006
Total Bio-Mass	764,725	538,348	748,660	716,684	449,890	686,703
Net Straw Recoverable	355,523	245,561	353,299	341,657	202,480	320,567

4.1.2 Complete a competitive analysis of Manitoba vs. other regions in Canada for straw types and availability.

In completing this section of the Study we have concentrated on the three western provinces of Alberta, Saskatchewan and Manitoba. These provinces produce the greatest volumes of straw in Canada and are therefore viewed as the major competitors when assessing Manitoba opportunities. Following is a breakdown of straw availability in the three provinces.

AVG 1994-2003 Grain Production: '000 tonnes				
	Alberta	**Saskatchewan**	**Manitoba**	**Total**
Wheat	6,557	11,748	3,642	21,947
Oats	815	1,353	884	3,052
Barley	5,491	4,294	1,470	11,255
Flax	31	552	295	878
Total	**12,894**	**17,947**	**6,291**	**37,132**
1994-2003 straw production: '000 tonnes				
	Alberta	**Saskatchewan**	**Manitoba**	**Total**
Wheat	8,524.1	15,272.4	4,734.6	28,531.1
Oats	896.5	1,488.3	972.4	3,357.2
Barley	6,040.1	4,723.4	1,617	12,380.5
Flax	37.2	662.4	354	1,053.6
Total	**15,498**	**22,147**	**7,678**	**45,322**
1994-2003 Straw Availability: '000 tonnes				
Total straw	15,495	22,091	7,649	45,235
Hectares straw/tonnes needed for conservation	-4,865	-8,985	-2,527	-16,377
Straw needed for cattle	-3,200	-1,800	-900	-5,900
Straw available after cattle and soil conservation	**7,430**	**11,306**	**4,222**	**22,958**
Available: percent available within each province	48%	51%	55%	

- Straw to grain ratio: Wheat 1.3 to 1, Barley 1.1 to 1, Oats 1.1 to 1 and Flax 1.2 to 1
- Straw needed for cattle calculated using Sokhansanj et. Al information.[11]

[11] Sokhansanj1, S., Mani1, S., Stumborg, M., Samson, R. and Fenton, J. Production and distribution of cereal straw on the Canadian prairies
Department of Chemical and Biological Engineering, University of British Columbia, Vancouver, British Columbia V6T 1Z3,
Canada; 2Semiarid Prairie Agricultural Research Centre, Agriculture and Agri-Food Canada, Swift Current, Saskatchewan S9H 3K2, Canada; 3Resource Efficient Agricultural Production (REAP) Canada,

- Straw to be retained for soil conservation is based on 1 tonne per hectare for all four crops.

While the above table provides an overall estimate of the straw that is available in each province it is a very poor indicator of the potential opportunities in each of these provinces for a straw based business. For this to be determined a detailed analysis would be required of the various regions within each province as it is widely recognized that some areas have high volumes of straw production and may be suitable while others are much the opposite. The remaining sections of this Study are more relevant in that they provide information as well as tools for determining the suitability of areas of Manitoba for establishing such businesses.

4.1.3 Identify breakdown of current uses of straw including processing, livestock use, soil incorporation, and straw burning.

In this section we have provided a breakdown of the current uses of straw in Manitoba in addition to a brief overview of each of these uses. The major uses of straw include being used for livestock feeding and bedding, soil conservation and nutrient replacement, burning and for flax fibre processing (in the case of flax). Other uses are also highlighted in the following table.

The discussion on the amount used for soil conservation and nutrient replacement focuses on the amount that **should** remain to maintain the on-going health of the soil including preventing soil erosion and replacing nutrients. This is not an indication of what actually does remain as it is expected that producers would be leaving more on the land than may be necessary, particularly those that are not burning and those that are using conservation tillage.

Current Uses of Straw			
Use of Straw			**Total**
Use by livestock	***Feeding***: 2.5 kg/hd/day x 150 days ***Bedding***: 2.5 kg/hd/day x 125 days	1,400,000 cattle (cows and calves)	***Feeding*:** 525,000 ***Bedding*:** 437,500 ***Total*:** 962,500 tonnes
Soil conservation and nutrient replacement	1.0 tonne/ha	1.94 million hectares of crop (wheat, oats, barley) 2001 census	1.94 million tonnes of straw
Burning	Heavily burned area	(estimate 40% of productive acres)	App. 437,723 acres[2]
Flax fibre processing	Remainder of Province	(estimate 2% of productive acres)	App. 50,000 acres[1] /yr

21111 Lakeshore Road, Ste-Anne-de-Bellevue, QuebecH9X 3V9, Canada; and 4Jim Fenton & Associates, 8 Graham Avenue, St. Albert, Alberta T8N 1T5, Canada. *Email:msudhagar@chml.ubc.ca

Schweitzer-Mauduit			
Erosion control blankets			Minimal
Farm and rural resident heating			Minimal
Processing for heat and energy			Minimal
Straw exported for use in dairy and horse markets			Minimal
Mushroom production			Minimal

[1] A small percentage of this acreage is from Saskatchewan and North Dakota. The acreage of flax is increasing in Saskatchewan and decreasing in Manitoba.
[2] 2007 estimates from MAFRI

Straw Use by Livestock

Sokhansanj et al, 2006 (Appendix A) in estimating the amount of straw available on the Canadian prairies determined that a figure of 5 kg/head/day for both feeding and bedding would be a conservative estimate. For Manitoba they estimated 150 days of feeding and 100 days of bedding and the calculations were based on the total cattle numbers. The Agricultural Fibre in Manitoba 2000 study used an estimate of about one tonne of straw per year per animal. They also approximated that barley straw contributed 80% and wheat straw 20%. [12] In their calculations they used the total cow/calf population and multiplied by one tonne of straw per year per cow/calf.

Based on further input from cattle producers and MAFRI Specialists it appears that an estimate of 5 kg/head/day (2.5 kg/head/day feed and 2.5 kg/head/day bedding) is a reasonable estimate. For the purposes of the above table and overall estimate of use the Study is using 150 days of feeding and 100 days of bedding. The total amount used is then multiplied by the total livestock numbers. Similar to the Fibre in Manitoba Study, this Study assumes that barley straw contributes 80% and wheat straw 20%. To some extent cattle feeding practices are changing as producers find ways to reduce feeding costs. For example some producers are feeding their cattle on the field thereby reducing the amount of bedding that is required. Practices such as swath grazing are also being increasingly used.[13] The Logistics Model enables the input of user defined information which can take into account variations in production practices and number of feeding and bedding days across the Province.

Straw use for soil conservation

Straw residue is important for the on-going health of the soil and to prevent wind and water erosion. The amount of straw that should remain on the land will vary according to the type of soil and the slope of the land. Based on current farming practices (Sokhansanj et al, 2006) concluded that "an average of 1 Mt/ha was assumed as a reasonable estimate of straw to be left on the land for soil conservation purposes".[14] Townley-Smith (2006)

[12] Agricultural Fibre in Manitoba Report prepared by Manitoba Agriculture & Food, January 2000.
[13] Inerview with MAFRI staff.
[14] Sokhansanj, S., Mani, S., Stumborg, M., Samson, R. and Fenton, J. 2006. Production and distribution of cereal straw on the Canadian Prairies. Canadian Biosytems Engineering Journal Volume 48, 2006

points out that most of the organic and soil carbon come from the roots and therefore, in some cases, the impact of the removal of straw may be minimal.[15] Appendix 1

In their analysis of the soil erosion impact Stumborg and Townley-Smith concluded that "750 kg ha^{-1} would be an adequate level of retained residues to prevent soil erosion from cereal production areas if no-till or reduced tillage systems were used by producers"[16] In assessing sustainability and economic issues for cereal crop residue export Stumborg et al. concluded that in the black soil zone reliable residues are available year after year. In reaching this conclusion they reinforced the need for producers to maintain adequate fertilization, use reduced or zero tillage and responsible crop rotation. [17] In Manitoba, outside of the Red River Valley, the use of reduced tillage practices predominates. Therefore this Study is using a conservative estimate of between 750 kg and 1000 kg/ha (890 lb./acre) of residue as an adequate level of residue that should remain for soil conservation purposes.

While this is the level that is being used for the Study we also recognize that soils vary considerably and the susceptibility to erosion also varies from one area to another. Therefore the Logistics Model enables the input of user defined information which can account for variations in soil quality and proneness to soil erosion.

Straw Use through Burning

In the following Rural Municipalities it was estimated that approximately 437,723 acres were burned in 2007: Macdonald, Morris, Cartier, Grey, St. Francis Xavier, Headingley, Ritchot, Montcalm, Rhineland, Franklin, Roland, de Salaberry, Stanley, Tache, Springfield, East St. Paul, West St. Paul, Rockwood, Rosser, Hanover and Portage la Prairie. Some of these RMs such as Rockwood, East St. Paul, West St. Paul, Stanley, and Tache appeared to have very little burning whereas others in this list were significantly higher.

Information was not obtained for the remainder of the Province although it would appear that burning of stubble is not near as prevalent in the remainder of the Province as it is in the RMs indicated above.[18] For the purpose of this Study it is assumed that 2% of the cereal acreage and 10% of the flax acreage for the remainder of the cropping area is burned.

Flax Fibre Processing

Schweitzer-Mauduit (S-M) is the main flax straw processor in Manitoba. They recently estimated that on average they process 100,000 – 120,000 ton annually from 200,000 – 250,000 acres. A small percentage of this acreage is from Saskatchewan and North Dakota. The acreage of flax is increasing in Saskatchewan and decreasing in Manitoba.

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[15] Townley-Smith, L. 2006 Update on GIS System for Biomass presentation to Whole Crop Utilization Workshop, Regina, Sk., March 6, 2006.

[16] Stumborg, Mark P.Eng. and Townley-Smith, Lawrence Ph.D "Agricultural Biomass Resources in Canada" Written for presentation at the 2004 ASAE/CSAE Annual International Meeting
Sponsored by ASAE/CSAE Ottawa, Ontario, Canada 1 - 4 August 2004

[17] Stumborg M, Townley-Smith L, and Coxworth E
SUSTAINABILITY AND ECONOMIC ISSUES FOR CEREAL CROP RESIDUE EXPORT
Available from Mark Stumborg stumborgm@agr.gc.ca
Agriculture and Agri-Food Canada/Agriculture et Agroalimentaire Canada
1 Airport Road, Box 1030 Swift Current, SK S9H 3X2

[18] Estimate of Acres Burned by MAFRI Staff - Obtained from Daryl Domitruk

With a permanent processing and storage facility located in Carman, Manitoba, S-M also has storage locations at Souris and Treherne. Portable decorticating plants process fibre at these locations. Flax fibre is extracted for use in the production of specialty papers such as cigarettes, currency, bibles, prayer books, artwork and stock and bond certificates.[19]

Erosion Control Blanket
This company is located in St. Andrews, Manitoba with a plant in Riverton. They use wheat straw in the manufacturing of erosion control blankets and sten logs as sediment control barriers.[20]

Farm and Rural Resident Heating
A small amount of straw is utilized by farm and rural residents in the heating of farm buildings and homes.

Processing for Heat and Energy
Companies such as Prairie Bio-Energy and Vidir Biomass are utilizing a small amount of straw in their operations in the production of heat and energy products. This amount is increasing as these two operations expand.

Straw exported for use in dairy and horse markets
This is another small but important niche market for some straw

Mushroom Production
One mushroom production facility exists in Manitoba. This facility utilizes straw as one of the components of the composted material.

4.1.4 Identify current and potential fibre processing markets for the different types of straw produced within Manitoba.

Based on the information obtained through the literature review and further investigation, this study has identified a number of current and potential uses for straw produced within Manitoba. These include:

- Utilization of Straw in producing Erosion Control Material
- Utilization of Straw for Heat and Power
- Densification of Straw to produce Pellets, Cubes, Briquettes and other Products
- Utilization of Straw in Composite Materials
- Utilization of Straw for Pulp and Paper Production
- Cellulose from Straw in Producing Ethanol/Biofuels
- Biomass to Bio-oil by Pyrolysis
- Maximizing the Value of Straw (biomass) through Bio-refineries

Utilization of Straw in producing Erosion Control Material

[19] "Flax Straw and Fibre" report on the Flax Council of Canada website available from: http://www.flaxcouncil.ca/english/index.php?p=growing12&mp=growing
[20] Alcock M & Boyko S "State of the Art Status of Biofibres in Canada: 2006" Prepared for the Composite Innovation Centre, Manitoba Inc. Report included as Appendix 4.

The Erosion Control Blanket Company with a plant in Riverton uses wheat straw in the manufacturing of erosion control blankets and sten logs for sediment control barriers.[21] Although the total volume of straw utilized by this company may be small it is an excellent example of one of the unique ways that straw can be used.

Utilization of Straw for Heat and Power

In this Study we have provided information on both combustion and gasification as options for the utilization of straw in the production of heat and power. In section 4.2.5 the Study outlines in more detail some of the combustion and gasification processes and provides examples of how this technology is being utilized.

Although the utilization of straw to produce heat and power in Manitoba is in its infancy this Study suggests that this could be an important future opportunity. Using straw to produce heat and/or power is quite far advanced in some European countries such as Denmark. The Secondary Information Review (Appendix A) and also section 4.2.5 provides examples of combined heat and power installations throughout Europe and also illustrates the district heating and power situation in Denmark. In a number of the installations, straw is first pelleted and then used in the pellet form as a fuel. Austria is another example where very advanced systems of district heating have been set up using a variety of feedstocks. Also, in Appendix 1, examples are provided of initiatives in this field in Canada and the US.

In Denmark, this move to utilizing biomass was driven by somewhat similar conditions to those that now exist in Manitoba. Renewable energy mandates were established for converting coal powered district heating plants and incineration plants to CHP plants. As well the utilities combined had to use 1.2 million tonne of straw and burning of straw on fields was prohibited.[22]

While the utilization of straw for heat and power in Canada and the US is not nearly as developed as Europe, there is growing recognition of the potential for using this biomass resource, in this manner. A number of factors are commonly sited as barriers to the development of this renewable energy sector including; supply infrastructure, conflicting demand for the feedstock, lack of familiarity with the technology, technology challenges and an unwillingness to explore alternatives. [23] [24] Of these the need to densify or compact straw is paramount in order to address the issues around the economics of supplying feedstock.

Although there are a number of challenges to the development of this sector it is also important to recognize that in Manitoba the combustion industry is quite well developed with a number of major companies specializing in the manufacturing of boiler/burner

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[21] Alcock M & Boyko S "State of the Art Status of Biofibres in Canada: 2006" Prepared for the Composite Innovation Centre, Manitoba Inc. Report included as Appendix 4.

[22] Sorensen HC UTILIZATION OF BIOMASS FOR PRODUCTION OF HEAT AND ELECTRICITY IN DENMARK WITH FOCUS ON THE DEMAND FOR R & D. EMU, Energy & Environment EMU@dk-online.dk http://www2.dk-online.dk.users/EMU pp. 583

[23] Article on Barriers to Widespread Use available from the Centre for Renewable Energy and Sustainable Technology website http://www.repp.org/bioenergy/link8.htm

[24] "Opportunity Fuels for CHP:Alternative to High Gas Prices? Presentation by Paul Lemar Jr to 5th Annual CHP Roadmap Workshop, Austin, TX 2004 Available at http://www.eere.energy.gov/de/pdfs/conf-05_chp_roadmap_wkshp/lemar.pdf

units. In addition to these companies there are also other initiatives in Manitoba that are focusing more directly on the utilization of straw in the biomass to energy process. Two examples of these Manitoba initiatives include:

Prairie Bio-Energy Inc.

- Prairie Bio-Energy Inc., located in La Broquerie**,** Manitoba
- Their mission is to use biomass as a renewable source of energy, by collecting waste and processing biomass into a solid fuel to offset coal.
- Currently they are producing 7/8 inch cubes from a mixture of wood, wheat straw and flax shives for use in solid fuel boiler systems to generate heat. [25]

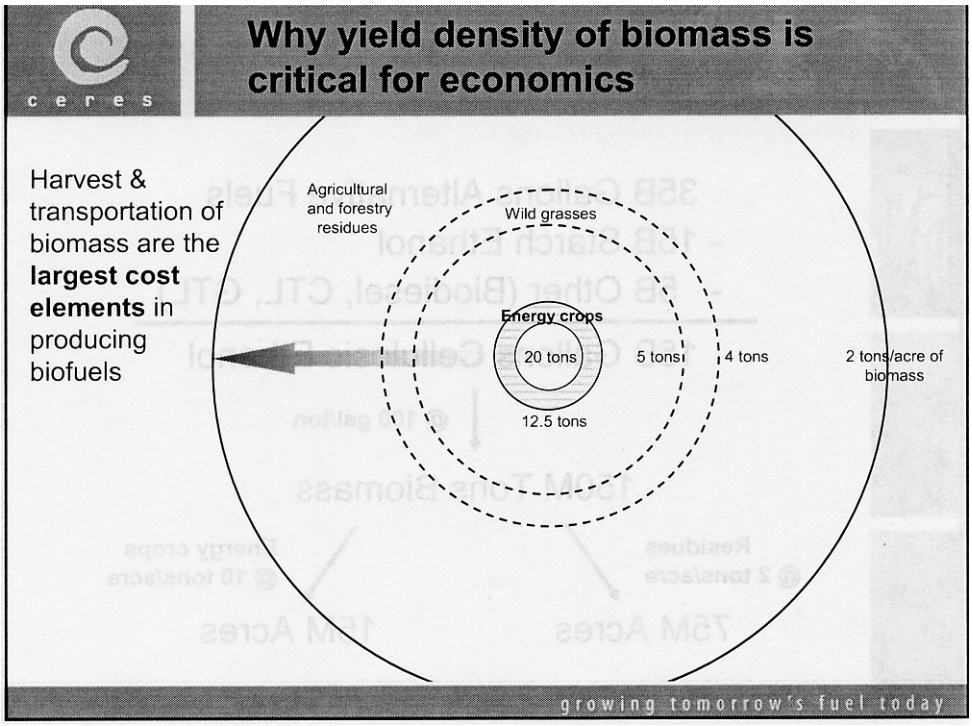
Vidir Biomass – Biomass Energy System Technologies

- Vidir Biomass Inc., headquarters in Arborg, Manitoba
- Utilizes their *VIDIR BEST* system featuring an updraft, atmospheric pressure heating system.
- The system uses straw or wood chips which is combusted on a grate.

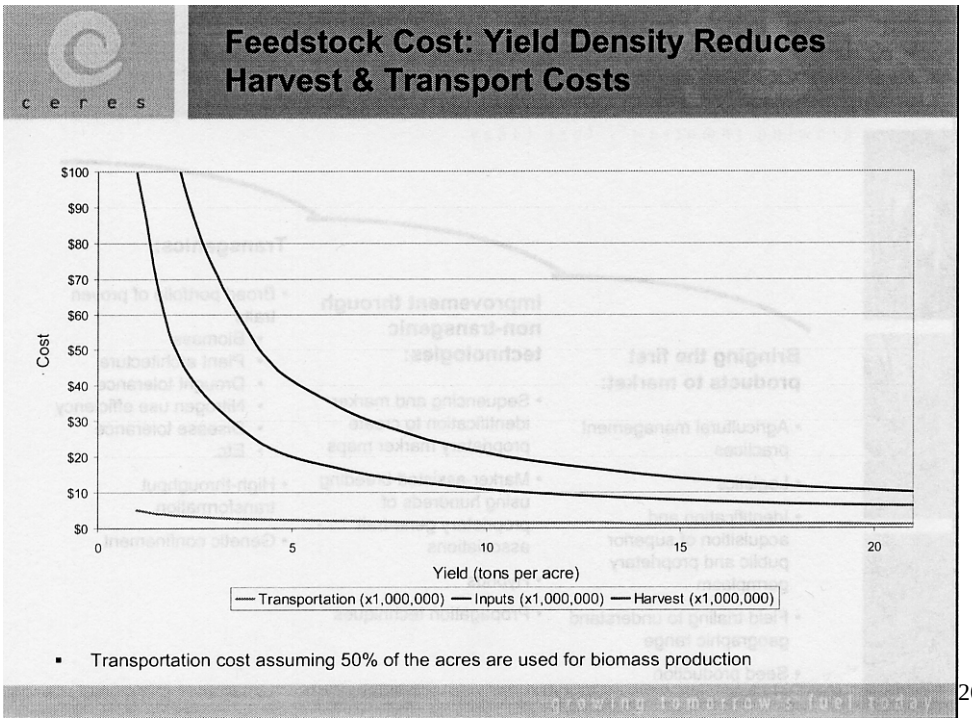
Densification of Straw to produce Pellets, Cubes, Briquettes and other Products

Densification of biomass

As an introduction to this section it is important to recognize perhaps the most limiting factor in the utilization of biomass feedstocks is the lack of density of biomass in cereal straws, corn stover and flax straw. Many of the technologies that are highlighted in this section focus on the issue of densification of biomass. The following two illustrations point out the direct relationship between harvest and transportation of biomass and the economics of energy production:



[25] Gauthier, Stephane Prairie Bio Energy Inc. presentation to ManSEA "Renewable Energy Opportunity – Making it Happen" workshops. Available from http://www.mansea.org/workshop.html



[26]

It is widely recognized that "Very attractive forms of biomass remain local and potentially not accessible to users worldwide because of the low energy density that makes long range transportation not economical"[27]

The conversion of straw to pellets is one method of densifying straw so that it can be more economically transported for use in heating and power facilities. The pelleting of straw also results in a fuel that is much more consistent with a greater ease of handling. The cubing process, used by Prairie BioEnergy, is another way to densify agricultural residues for this purpose. Countries, such as Denmark, have considerable experience in the straw to pellet process. Appendix 1 of this Study provides a more detailed description of some of the opportunities and obstacles in the straw to pellet process. Suffice to say that probably the major obstacle is the amount of ash that straw pellets produce resulting in a need to use this type of pellet in large scale plants with advanced combustion technology.

Utilization of Straw in Composite Materials

The utilization of straw in the production of composite materials is an area that has gained a lot of attention over the past few years.. The Secondary Information Review (Appendix 1) provides a more detailed description of some of these processes. The Composites Innovation Centre (CIC) has completed extensive studies into the use of biofibres in composites. The CIC document "State of the Art Status of Biofibres in Canada: 2006," Appendix 4 provides a more thorough overview of this industry. While there are many current and potential uses of straw in composite materials the main areas

[26] Swayze Spencer "Biofuels: The Role of Dedicated Energy Crops" Presentation to Biomass 07 Grand Forks, May 2007

[27] Zullo L. "Can Technologies for Energy Densification Make Biomass a Worldwide Tradeable Energy Supercommodity" Presentation to Biomass 07 Grand Forks, May 2007

of focus in Manitoba are in the areas of hemp fibre development, hemp use in composites as well as flax fibre in composites. The following excerpt from a CIC newsletter sums up the situation regarding the utilization of flax and hemp fibre in composites:

> "the CIC recently performed a study that assessed the financial viability of producing and processing agricultural fibres from oil seed flax and industrially grown hemp. The costs for gathering and processing the fibres, using several techniques, were determined and compared against current prices for traditional fiberglass reinforcement materials being manufactured in both North America and Asia. Alternate business models were examined and it was determined that, in most cases, there were good returns to be made. "There's a huge potential for a processor to commercialize here in Canada" said Mercedes Alcock, Bio-Composites Project Leader, after compiling the data and completing the report, "Manitoba in particular is in a great position to capitalize on this opportunity as it has both the acres and the industry to support a venture."

While the main area of emphasis in Manitoba appear to be in the use of flax fibre mat use to replace E-Glass in composite materials there is also considerable interest in the utilization of flax shives in bio-composite materials and in flax fibre use in green insulation.

Utilization of Straw for Pulp and Paper Production

Although the production of pulp and paper from straw is possible, there have been few commercial developments in this area on a worldwide basis. In North America and much of Europe the use of cereal straws in the pulp and paper industry have given way to wood pulp which is more economical.[28] Given the difficulties that the pulp and paper industry in general is facing, this Study suggests that this should not be an area of emphasis for Manitoba at this time.

Cellulose from Straw in Producing Ethanol/Biofuels

In assessing current and potential uses of straw one of the very promising technologies is that of lignocelluloses to ethanol. In the move towards utilization of renewable energy sources and reduction in greenhouse gases, a great deal of emphasis is being placed on the development of this technology. There is a number of cellulose to ethanol initiatives that are gearing up for commercialization. The US Department of Energy is providing funding support for a variety of processes in the cellulose to ethanol field.[29] Appendix 1.

Questions regarding the production of ethanol from cellulose include: "when will we see a commercial plant in operation" or "when will ethanol production from cellulose to ethanol be competitive with grain based ethanol processes"? While some industry experts predict that this will be quite soon (2009), others suggest that it may be more like

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[28] Cooper PA & Balatinecz JJ, Faculty of Forestry, University of Toronto and Flannery SJ, Isobord Enterprises Inc. AGRICULTURAL WASTE MATERIALS FOR COMPOSITES: A CANADIAN REALITY pp. 6
Presented at: Centre for Management Technology GLOBAL PANEL BASED Conference, Nikko Hotel, Kuala Lumpur, 18-19 October, 1999.
Available from: http://www.forestry.utoronto.ca/treated_wood/agriwaste.pdf

[29] DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding, February 28, 2007
DOE Press Release available at: http://www.doe.gov/news/4827.htm

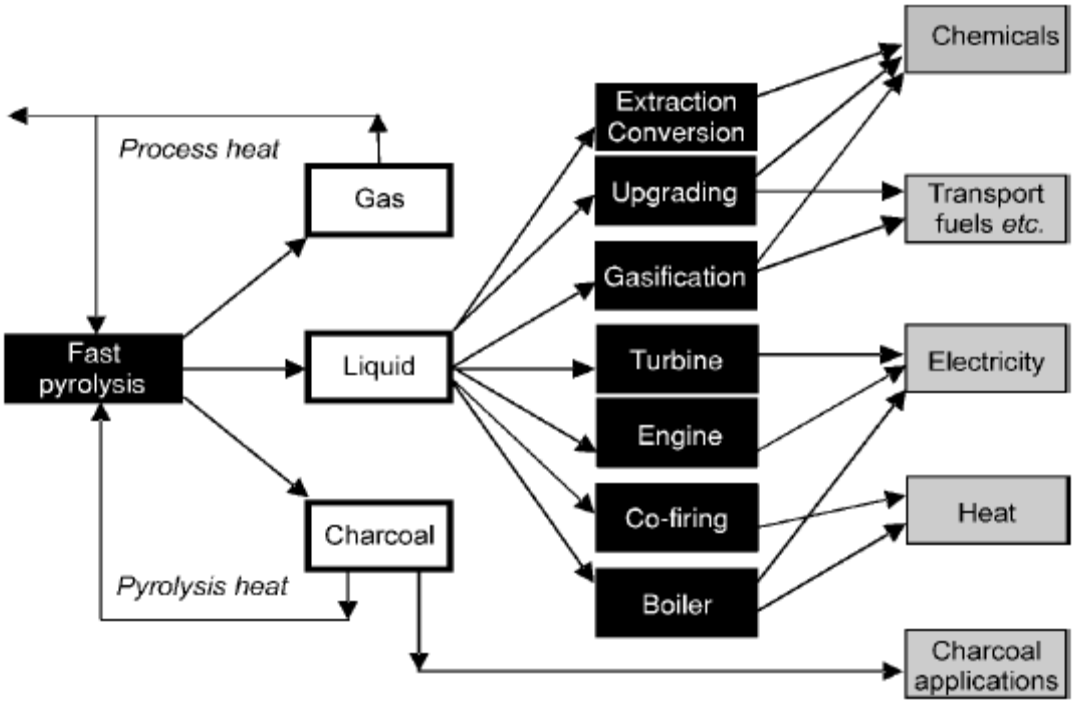
2010 – 2017. While the development of the technology is a very important component in the drive to commercialization, the other important factor is the very large volumes of biomass feedstock required to operate an economically viable plant (500,000 – 1,000,000 tonnes).

Much of the emphasis in the cellulose to ethanol field has been on the potential of utilizing agricultural residues such as wheat straw and corn stover as feedstocks. There is now, a growing recognition that energy crops such as switchgrass, hybrid willow and hybrid poplar can also provide the fuel for this process. Given the large volumes of straw produced in some areas of Manitoba combined with the ability to produce other energy crops, the potential for a straw to ethanol business should be considered.

Biomass to Bio-oil by Pyrolysis

The following diagram illustrates the process of pyrolysis. In this illustration the process is referred to as fast pyrolysis. The terms fast and flash pyrolysis are both used in referring to this process which involves a very rapid heating of particles followed by very rapid cooling. They are sometimes differentiated one from another based on the temperature used in the process.

Fast pyrolysis and uses of the products



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[30] *BRIDGWATER A.V.* BIOMASS FAST PYROLYSIS 2004
THERMAL SCIENCE: Vol. 8 (2004), No. 2, pp. 21-49
Available from: http://thermalscience.vin.bg.ac.yu/pdfs/2004-2/TS22004Cl2.pdf

In **flash pyrolysis** there is very rapid heating of the biomass particles for a very short time period followed by a rapid cooling of the gas, resulting in mostly liquids being produced. In the pyrolysis process the feedstock is dried and ground in order to meet the specified requirements of the pyrolysis process. There are several types of reactors that can be used in the pyrolysis process such as fluid bed reactors and rotating cone technology. In the flash pyrolysis process, occurring at very high temperatures, mostly liquids are produced in the process whereas in other pyrolysis processes which perform at lower temperatures there is more charcoal and gases produced.[31] [32] Although much of the technology of pyrolysis is still in the pilot and demonstration phase there are rapid advances towards commercialization.[33] Canada is a leading country in the development of pyrolysis technology. The US Department of Energy EERE website provides an excellent overview of the pyrolysis processes.[34]

The following are some examples of pyrolysis initiatives:

Pyrolysis Initiatives

Dynamotive Energy Systems and Evolution Biofuels

- Building modular decentralized fast-pyrolysis plant in Guelph, Ontario
- Will convert wood residues to bio-oil
- 200 tonnes/day
- Will consist of eight modules that can be transported and set up on site.[35]
- Dynamotive Energy Systems uses feedstock such as sawdust or bagasse from sugar cane (<10% moisture and 1-2 mm particle size) in a fast pyrolysis process (450-500 degrees Celsius). A bubbling fluid bed reactor is used in this process. The BioOil that they produce contains up to 25% water. Dynamotive is doing extensive testing of this BioOil in various commercial applications.
- Dynamotive's testing of other feedstocks provides the following information which illustrates the potential BioOil yield from wheat straw using this process:

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[31] van Thuijl E, Roos CJ & Beurskens LWM (2003) AN OVERVIEW OF BIOFUEL TECHNOLOGIES, MARKETS AND POLICIES IN EUROPE (pp 20-22) Energy research Centre of the Netherlands, ECN Policy Studies, P.O. Box 37154, 1030 AD Amsterdam, The Netherlands
Email: vanthuijl@ecn.nl

[32] "Straw for Energy Production Technology-Environment-Economy" A report by The Centre for Biomass Technology, Denmark Report available from http://www.videncenter.dk/uk/index.htm

[33] European Market Study for BioOil (Pyrolysis Oil) (2006) (pp 3) by Climate Change Solutions, 402 Third Avenue ·Ottawa, Ontario ·Canada K1S 2K7
phone · 613.321.2303 email ·douglas.bradley@rogers.com Available from: http://www.bioenergytrade.org/downloads/bradleyeuropeanbiooilmarketstudyfinaldec15.pdf

[34] U.S. Department of Energy EERE website: http://www1.eere.energy.gov/biomass/pyrolysis.html

[35] "Dynamotive begins construction of modular fast-pyrolysis plant in Ontario" December 19, 2006 Biopact Press Release Available from: http://biopact.com/2006/12/dynamotive-begins-construction-of.html

Yields Rate of Various Feedstocks

Feedstock	BioOil yield (Wt% mf)	Char yield (Wt% mf)	NCG yield (Wt% mf)
Corn Hulls	80.4	12.1	6.8
Spruce	73.8	8.1	16.3
Larch	72.9	12.7	10.3
Sugarcane bagasse	72.7	14.8	8.2
Pine/Spruce Mix	70.3	14.3	13.4
Western Cedar	68.8	14.1	7.1
Switch Grass	58.7	13.8	13.4
Wheat Straw	58.7	13.8	13.4

[36]

Advanced BioRefinery Inc. (ABRI)

- Head office in Ontario
- Prototype 1 tonne/day dry plant being tested.
- 50 tpd plant expected to be operational in early 2007 and in process of ramping up in late 2007. This plant was purchased by Ontario Ministry of Natural Resources to convert wood residue to liquid.[37]

Ensyn Group Inc.

- Uses a fast pyrolysis process called Rapid Thermal Processing or (RTP™) technology. "At a temperature of around 500°C, much lower than combustion or gasification, the turbulent hot sand instantly flashes the biomass into a vapour, which is then cooled, condensed and recovered as a liquid product."
- Feedstock is wood residue
- Plant in Renfrew, Ontario (near Ottawa) converts 200 green tpd into "natural resin products, co-polymers, other chemicals, liquid fuel and green electricity".
- Four RTP plants in commercial operation (three in Wisconsin and one near Ottawa).[38]

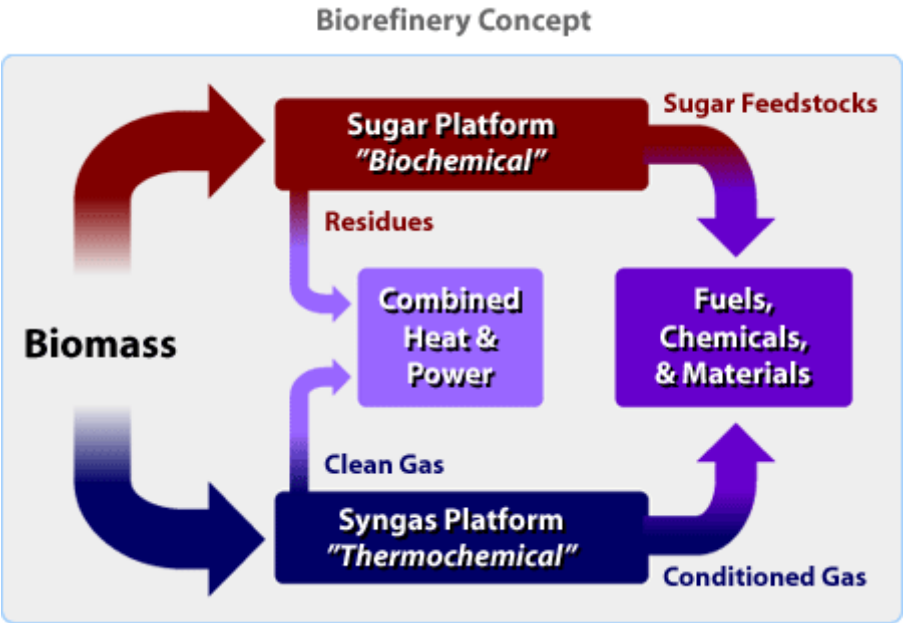
While the pyrolysis process would seem to be the type of technology that could be located in areas close to the straw supply and therefore address some of the economic challenges of transporting straw long distances, it appears to be a process requiring much more research and development. This is particularly so given that much of the initial development of this process focuses on utilizing wood residues as the primary feedstock.

Maximizing the Value of Straw (biomass) through Biorefineries

[36] Dynamotive Energy Systems Corporation website. Available at http://www.dynamotive.com/index.html
[37] Advanced BioRefinery Inc. Corporate History and Structure (ABRI) website http://www.advbiorefineryinc.ca/about.html
[38] Ensyn Group Inc. website at http://www.ensyn.com/info/23102000.htm

The biorefinery concept and the process of utilizing straw and energy crops in the production of multiple products is an area that is receiving much attention as the world searches for more environmentally friendly and economically viable processes. It is helpful to define what a biorefinery is. The following excerpt from the NREL website provides a brief overview of this concept:

"A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass. The biorefinery concept is analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum. Industrial biorefineries have been identified as the most promising route to the creation of a new domestic biobased industry.



By producing multiple products, a biorefinery can take advantage of the differences in biomass components and intermediates and maximize the value derived from the biomass feedstock. A biorefinery might, for example, produce one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel, while generating electricity and process heat for its own use and perhaps enough for sale of electricity. The high-value products enhance profitability, the high-volume fuel helps meet national energy needs, and the power production reduces costs and avoids greenhouse-gas emissions."[39]

An integrated biorefinery has many benefits because of the diversification of feedstocks and products. Feedstocks such as grain, cereal straws, energy crops, forest residues and paper mill waste can all be utilized in an integrated biorefinery in the production of fuels, chemicals and heat and power. [40]

[39] "Strategic Biorefinery Analysis: Analysis of Biorefineries" 2002 L.R. Lynd, C. Wyman, and M. Laser *Dartmouth College Hanover, New Hampshire* D. Johnson and R. Landucci *ProForma, Inc. Golden, Colorado* Available from: http://www.osti.gov/bridge/

[40] USDOE Website on the Biomass Program and Integrated Biorefineries http://www1.eere.energy.gov/biomass/integrated_biorefineries.html

Daryl Domitruk, MAFRI, builds on the biorefinery concept and the efficient use of feedstocks such as straw and energy crops and proposes that "By capturing opportunities in the Bioeconomy agriculture becomes a solution provider for a healthy, sustainable and prosperous Canada"[41]

Agriculture in Manitoba including the utilization of straw and the ability to produce energy crops lends itself to the development of biorefineries. While this may only materialize over the long term there appears to be a need now to start working towards this longer term goal.

4.1.5 Identify and/or develop quality parameters for each end use of the fibre. That is, for each product produced from fibre, what are the desirable qualities of the straw and identify Manitoba supply of these qualities.

Straw quality is a very important factor in developing a straw based business. It is well recognized that the more consistent the quality of straw, the better. The more homogeneous the biomass is the more easily it can be processed.[42] [43] This is a challenge in that; in general straw fibres have a greater variation in quality than other fibres.[44] [45] [46] [47] As well there are a number of factors that can influence the end quality of feedstock including the type of harvesting system, the baling process and how it is stored.
In Appendix 1 the Study provides an overview of the straw quality parameters for the many different uses of straw. The following Table provides a detailed outline of the straw quality needs for the three business case scenarios (fibres of focus).

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[41] "Bioenergy: Feedstock and the Bioeconomy" presentation by Daryl Domitruk, MAFRI, Morden, Manitoba, Feb. 2008.
[42] Chornet, Esteban (Enerkem Technologies Inc., University of Sherbrooke) Presentation at Capturing Canada's Natual Advantage workshops in Edmonton and Montreal November 2005.

[43] Paquette, Christine 2007 Correspondence from the Composite Innovation Centre regarding a harvesting study. Information available from Christine Paquette, Director, Biomaterials Initiative, Composite Innovation Centre Manitoba Inc. cpaquette@compositesinnovation.ca
[44] Cruickshanks, Bill, 2002 "Conversion of Crop Byproducts to Fuels" " A presentation to Ag Fibre 2002 Conference, Winnipeg, MB, Canada. November 13-15, 2002.

[45] Smeder, Bo, 2002. Factors Influencing the Business-to-Business Buying Behaviour of Straw-Based Products" A presentation to Ag Fibre 2002 Conference, Winnipeg, MB, Canada. November 13-15, 2002.

[46] Ulrich, Alvin 2002 "Assessing Straw and Fiber Quality" A presentation to Ag Fibre 2002 Conference, Winnipeg, MB, Canada. November 13-15, 2002.

[47] Hjuler, Klaus 2007 "The quality of pellets made from alternative biomass" Presentation to World Sustainable Energy Days, Wels, Austria 2007

Quality Parameters for Different Uses			
Usage	***Applicable Crop***	***Process Quality Needs***	***Quantity Available***
Biomass to Heat and Power Cubes	Cereal straws, corn stover, flax shives	▪ Prefer biomass with high bulk density, low alkali metal content, low ash content and high energy value ▪ Quality of biomass required will depend on the combustion system being used and the ability of the system to take material with higher ash content and high alkali metal content.[1] ▪ Low moisture content – target MC 17% although usually in range of 15-20% ▪ Material ground in initial processing so can handle wider variations in size of feedstock material. ▪ Wheat and oat straw approx. 7200 btu/lb. and barley straw slightly less ▪ Energy value of feedstock can vary with type of soil in area. ▪ Ash content and ash composition will vary depending on the soil.	▪ Estimate 85-95% suitable[2] ▪ The product produced in this business may be composed of a mixture of feedstocks including cereal straw, flax shives, wood and recycled cardboard. ▪ Ample quantities of feedstock appear to be available in a number of areas in Manitoba.
Biomass to Heat and Power Pellets	Wheat straw	▪ High content of alkali chloride in straw which leads to high risk for corrosion and fouling in the boiler. ▪ High level of silica in straw can lead to greater abrasion in pellet plants and therefore a need to replace parts more often. ▪ High ash content can lead to greater problems in combustion units. ▪ High ash content can lead to more ash disposal concerns.	▪ Estimate 75-90% suitable ▪ Ash composition to some extent dependent on nutrient/mineral content of soil that straw is produced on. ▪ Further investigation could lead to straw quality more suited to pelleting process.
Industrial Uses of Flax such as in	Flax	▪ Fines are a problem ▪ Need consistent quality of straw	▪ Much of the investigation into the use of flax fibre for

Composites		▪ Fibre length important with longer fibres preferred particularly for some applications such as flax mats for E-Glass replacement. ▪ For high end composites, preferred that flax straw be consistent in length, stem diameter, fiber content and degree of retting. ▪ Higher fibre yields and quality are desirable in utilizing flax fibre to replace E-Glass. This may be accomplished utilizing a managed straw system.[48] ▪ Retting of flax straw is an important quality consideration	composites (E-Glass Replacement) has assumed that the flax fibre used would be from flax oilseed varieties. ▪ The flax variety affects both fibre and seed yield. ▪ The quantity of flax straw available varies from area to area and further specific investigation would be required to determine availability. ▪ Schweitzer Mauduit takes much of the flax straw produced in Manitoba and any new venture would need to take this into account. Schweitzer Mauduit is a partner in many of the flax to composites projects and may play an important role in providing processed flax fibre to a flax to composite business. ▪ Harvesting method may affect the quality of flax straw (fibre). ▪ Very difficult to estimate the amount that would be

			suitable without knowing the specific use of the flax fibre.
Cellulose to Ethanol	Wheat, barley, oat and rye straw	▪ Feedstock consistency is important although may not be a critical issue. ▪ The moisture content will be dependent on the process being used. For the Iogen process there is no ideal moisture content of the straw coming into the plant as they wet the straw right away. ▪ Iogen would likely pay on a bone dry basis. ▪ Moisture content is important if the straw is to be baled then absolute maximum 20% MC with 18% being safe. This could be more like 10% on a very hot fall day.	▪ For the pre-treatment process of cellulose to ethanol you do not want a lot of variation in the cellulose, hemi cellulose and lignin content from one feedstock to another. This is probably not a major problem for crops such as wheat, barley, rye as you can probably segregate the feedstock and vary the pre-treatment process to take into account variations. ▪ Estimate 70 – 85% suitable.
Composting (bagged or used as a soil amendment).	All cereal straws, corn stover and flax shives	▪ Composting could accept a very wide range in quality of unutilized material from straw businesses. ▪ Moisture content could be quite high.	▪ The amount of suitable material will depend on the processing business to which a composting operation is associated. ▪ With a large scale cellulose to ethanol plant there should be very little material from the plant that would need to go into a composting operation unless there is feedstock material that is not suitable for putting through

			the plant. ▪ With a biomass to heat plant there may be feedstock material (straw) that is too high in moisture or has deteriorated in some other way to make it unsuitable for cubing or pelleting.

1. PAMI in cooperation with MAFRI and Prairie Bioenergy are doing combustion trials on cubes produced from this process. These trials are being conducted using a coal burning combustion unit. The cubes are produced from pure wheat straw, pure barley straw or pure oat straw.

2. The quantities that would be suitable are only estimates and any prospective business would need do significant additional work in determining the quantities of material that are suitable.

4.1.6 For each fibre end use, identify the requirements for straw storage and how this will affect the procurement costs.

This section contains descriptions of the storage requirements of businesses in Manitoba which have used, are using or plan to use straw fibre. In addition, estimates of the costs of various types of storage are presented.

Storage Parameters for Different Uses		
Usage	***Applicable Crop***	***Storage Needs***
Biomass to Heat and Power ▪ Cubes	Cereal straws, corn stover, flax shives	▪ Storage may be required to maintain the moisture between 15 and 20 % ▪ Moisture content of 17% is desired
Biomass to Heat and Power ▪ Pellets	Cereal straws, flax shives	▪ Good quality and consistency is required; hence, high quality storage is required ▪ Alternatively, the ability to select high quality straw from a large supply with other markets for the lower quality straw
Biomass to Heat and Power ▪ Round bales	Cereal straw, flax bales	▪ Storage requirements are minimal ▪ Stacking technique helps to avoid moisture uptake (bottom row of bales on end and top row on side)
Industrial Uses of Flax such as in Composites and in Paper	Flax	▪ Round bales are tarped. No preparation to the base (so that the land can be returned to farm production after the bales are removed) ▪ Retting of flax straw is an important quality consideration and various options are being considered to increase the retting. (ie. Spring baling)
Cellulose to Ethanol ▪ Round bales	Wheat, barley, oat and rye straw	▪ Storage requirements are minimal since additional feed stock prices are to be avoided

In order for a producer to implement storage procedures which are in addition to usual practice the contractual arrangement must be acceptable to the producer.

On Page 67 of the Secondary Information Review, reference is made to a study done for the Chariton Valley Biomass Project (Draft Fuel Supply Plan) in 2002 which assessed the storage requirements and compared various storage options for the securing of up to 200,000 tons of biomass annually from 50,000 acres and involving as many as 500 farmers. The six storage methods studied included outside unprotected (on-ground or on-crushed rock), reusable tarps, pole -framed structures (open-sided or enclosed), and steel sheds. The following table presents a summary of the storage costs.

Exhibit 3-13 Off-Site Storage Cost Summary Table

Storage Method	Cost w/o Dry Matter Loss ($/ton)	Dry Matter Loss at $50/ton	Cost w/Dry Matter Loss ($/ton)	**Project Cost** ($/ton) (82% SWG requiring off-site storage)
Reusable tarp on crushed rock	$5.03	$3.50	$8.53	**$7.00**
Outside, Unprotected on crushed rock	$1.07	$7.50	$8.57	**$7.03**
Pole frame structure–open sided on crushed rock	$6.62	$2.00	$8.62	**$7.06**
Pole frame structure–enclosed on crushed rock	$13.24	$1.00	$14.24	**$11.68**
Pre-manufactured steel storage shed	$16.10	$1.00	$17.10	**$14.02**

4.1.7 Analysis of how Manitoba straw producers could change or improve their operations to meet these straw quality standards. i.e.: equipment modifications to improve quality or volume, harvesting operations – conventional vs. rotary combines, harvest timing, varietal selection, etc.

In the Secondary Information Review a few items were identified as within the control of Manitoba straw producers as they consider changing or improving their operations to meet straw quality standards. These items included the types of combines used, the settings employed, the height of the stubble and the varieties grown. For details please see pages 68 to 70 of the Secondary Information Review (Appendix 1).

In the Producers Focus Group and in the Producers Survey the following points were raised:

- In areas of high straw production producers have a desire to have commercial or industrial use of their straw rather than burning

- The trend appears to be toward a greater percentage of rotary combines; there is a recognition that a greater quantity of straw can be recovered from conventional combines; there is a recognition that adjustng the settings on rotary combines can have a significant impact on the quality of straw produced
- Some large grain farms may not be willing to change their operations to accommodate straw collection
- The amount of the financial incentive offered will significantly influence the producer's decision regarding changes to farm operations

The Custom Operator Focus Group and the Custom Operator Survey clarified and emphasized some of the issues in which the custom operators are intimately involved:

- There is a recognition that some custom operators who have not been paying the producers for their straw may have to start paying for the product
- Communication is very important in the contractual arrangement between the producer and the custom operator.

Please refer to Appendix 2, Primary Research Information, for comments from producers and custom operators.

The experiences of related fibre ventures have something to offer in terms of being able to influence quantities of fibre available. Quality can be preserved through investment in storage as Sunridge Forage of Russell has done. Different varieties have the potential of significant increases in production as Parkland Industrial Hemp Growers of Dauphin is aware. The logistics of the baling process can benefit from careful attention and planning as the Straw Producers Coop of Manitoba was well aware.

The quantity and quality of flax fibre are important considerations when assessing potential industrial uses of flax straw. The flax fibre quality needs depend on the end process needs. The Composite Innovations Centre is working with PAMI and Schweitzer Mauduit in investigating harvesting processes, quantity of flax fibre, quality of fibre and varieties.. These studies are using various options such as straight cut header, stripper header, mower conditioner and swather. Some of their findings include:

- There is significantly more volume with conventional combines
- With rotary combines the flax straw was more chopped up and finer.
- With the stripper header the straw was trampled by combine tires to some extent.
- The quality of straw: conventional 18" – 22" in length, rotary 7"-14" in length
- There was much longer fibre with the stripper header. Harvesting systems research reported by Stumborg concluded that with a rotary combine the grinding action leaves less baleable straw and that the grinding action of the rotary combine may either enhance or worsen further processing.[49]
- Harvest method impacts seed yield as well as quantity and quality of fibre.
- Research is on-going.

The bottom line in assessing harvesting systems is that any changes in flax harvesting systems have to be economical to both producers and processor. There are varietal differences in fibre content with flax. Much of the research work on fibre content is with

flax oilseed varieties rather than fibre flax varieties, even though fibre flax varieties would be much higher in fibre. There is recognition that producers will not readily make the switch from oil varieties to fibre varieties unless it is profitable for them to do so. The total dollars returned have to offset the cost of switching to fibre flax varieties.

4.1.8 Economic analysis for the farmer treating the straw as a commodity rather than as a worthless bi-product. If the straw quality standards are met for the fibre markets already identified, what, if any, economic benefit would there be to the farmer.

This section presents a qualitative discussion of the factors which agricultural producers may take into account when determining how much they believe the straw produced by their crops is worth. Key informants, agricultural producers and custom operators provided opinions and issues related to this valuation.

On Page 71 of the Secondary Information Review a chart was included providing estimates of the dollar value of nutrient losses from straw removal and straw burning. For example, in the 2001 Manitoba study by Heard et al., the estimate for the loss in nutrient value through straw removal for wheat straw was $11.15 to $16.25 per acre. In Section 4.3.13 of this report the estimates of these values of nutrient losses are updated to account for the increases in the prices of fertilizer.

It is readily evident that the perceived value of straw varies from one area of the Province to another and from one year to another. In general, the Red River Valley area produces a significant quantity of straw and the soil of the area presents a challenge to producers in their attempts to incorporate crop residue into the soil. In other areas of the Province the general practice is to chop and spread most of the straw in the harvesting process. Areas with substantial livestock populations require a significant portion of the straw for feed and bedding.

The following chart summarizes the comments of producers and custom operators provided through the focus groups and surveys. The topics investigated included the removal of straw through baling and burning and the retention of straw through incorporation and spreading.

Technique	Comments in Favour	Comments Against
Removal by baling	▪ Source of additional revenue ▪ Needed for livestock use	▪ Time delay in field operations ▪ Nuisance of twine left on the field
Removal by burning	▪ Higher yielding crops by drying the soil	▪ Environmental concerns of smoke in the air ▪ Removal of nutrients since the ash has less nutrient value

Retention by incorporation	▪ Organic matter is retained ▪ Nutrients retained	▪ Expense of tillage operations
Retention by spreading (no till)	▪ Soil conservation	▪ May leave excess residue on the surface

From the Producer Survey the perceived value of the straw for soil nutrients ranged as follows on a per acre basis:

Wheat	$4.00 to $40.00
Barley	$4.00 to $40.00
Oats	$4.00 to $40.00
Rye	$4.00 to $40.00
Flax	$0 to $30.00
Corn	$10.00 to $40.00

This wide range in perceived values suggests a need for additional research to contribute to our understanding of the nutrient value of straw. One producer commented that "they knew the straw was a nutrient source but didn't know how to put a value on it." Another stated that "even with the straw incorporated he still had to apply the required amount of fertilizer because the straw seemed to use up some of the fertilizer."

4.1.9 Identify the fibres of focus for Manitoba based on information gathered.

As a result of the information gathered during the Secondary Information Review and the subsequent analysis of this information a number of fibres of focus were identified for this Study. The approach utilized was to look at processing that has the potential to be commercially feasible in the short term (3-4 yr). The following table outlines the potential usage, the crops of focus and additional crops that could be considered for this usage:

Usage	Crop of Focus	Additional Potential Crops
Biomass to heat	▪ Wheat and winter wheat ▪ Barley ▪ Oats ▪ Rye ▪ Flax shives ▪ Corn stover	▪ Hemp hurd ▪ Hybrid poplar ▪ Short rotation willow ▪ Switchgrass ▪ Sunflower seed hulls

Industrial uses of straw to produce composites	▪ Flax fibre	▪ Hemp fibre ▪ Wheat ▪ Oats
Large scale (cellulose to ethanol)	▪ Wheat and winter wheat (main crop of focus) ▪ Barley ▪ Oats ▪ Rye ▪ Corn stover	▪ Hybrid poplar ▪ Short rotation willow ▪ Switchgrass

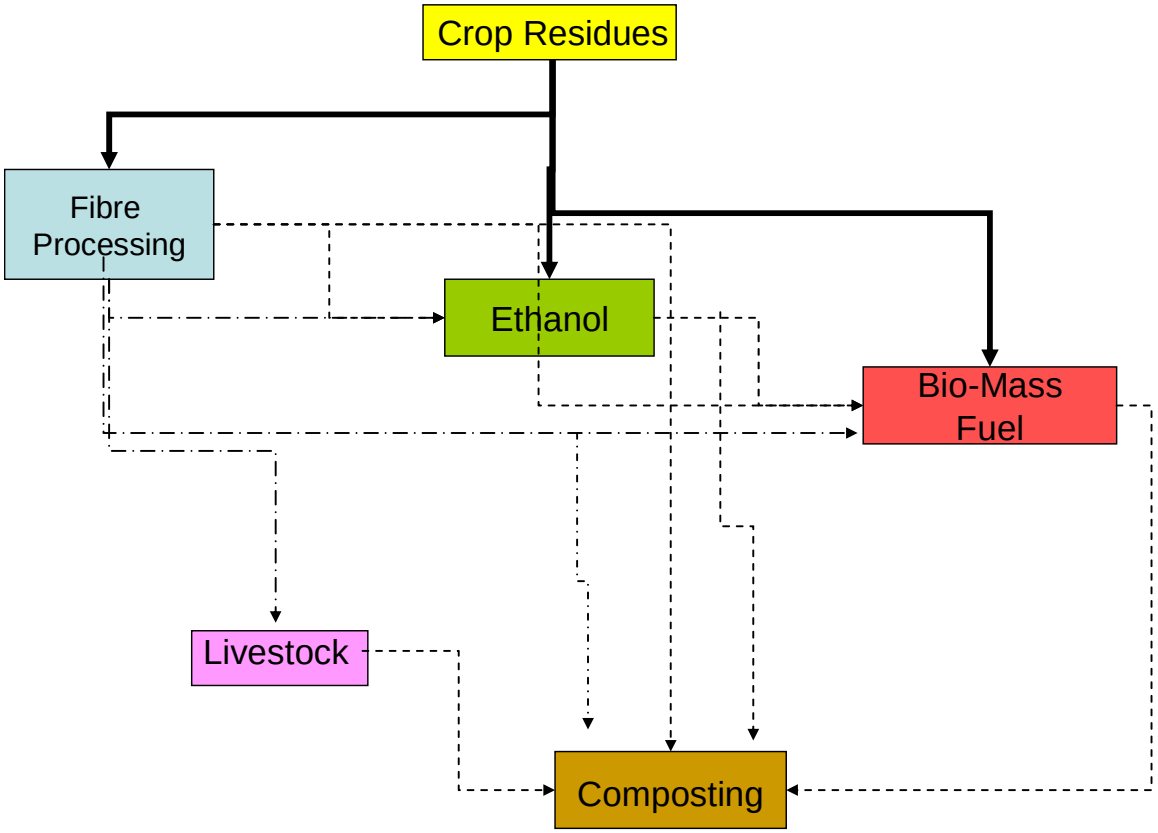
4.2.1 If primary intended user would no longer require the secured straw, what are the potential alternative uses for the straw supply sitting on-site?

Section 4.1.4 explored alternative uses for crop residue materials in Manitoba and other locations around the world. Section 4.1.5 also discussed quality parameters required for each process.

Overall, the fiber processing business models appear to be the most demanding of primary processors in terms of quality of feedstock, followed by cellulosic ethanol and then bio-mass energy production (either pellet or direct). Livestock needs and composting inputs may represent the least demanding uses of crop residue materials.

The following chart presents an illustrative indication of how secondary uses could be explored for crop residue materials beyond the primary user.

Alternative Uses of Crop Residue Materials



4.2.2 Evaluate cost of moving straw from main/satellite sites to different locations, possibly at much longer distances.

The cost of moving crop residues from main or satellite sites to different locations is dependent on several factors, including:

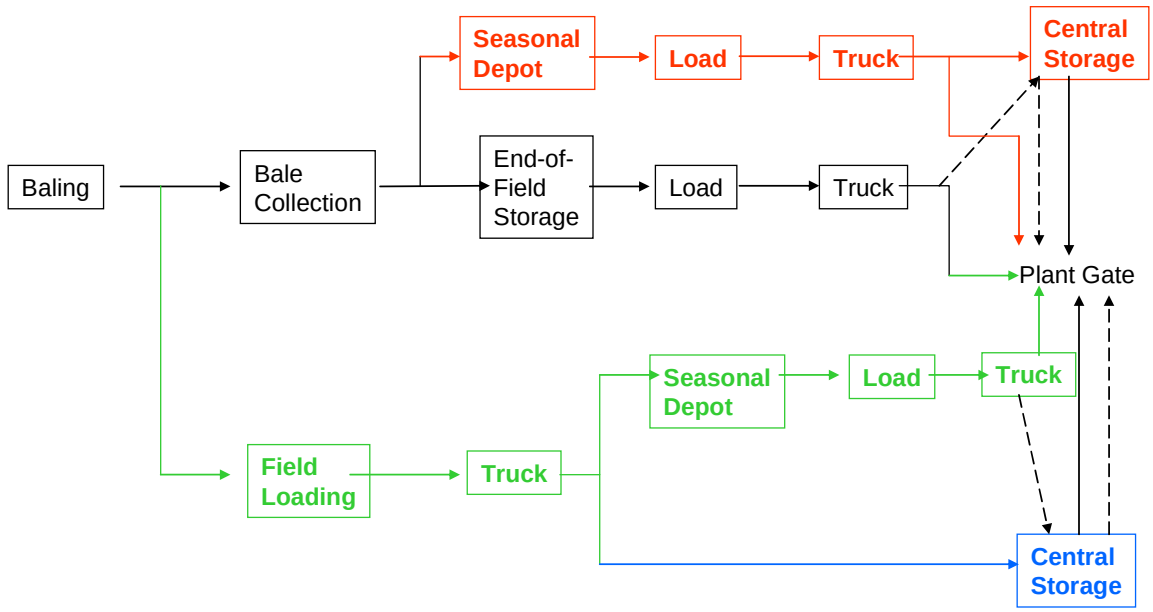
- the density of the product
- the ease of handling the bales
- the conditions of the bales
- ease of access to the site.

Moving crop residues from a main or satellite location to a different location will involve two primary costs, namely loading costs and transportation costs. While these costs are discussed in more detail in Section 4.3, the following summary observations can be made:

- Loading costs will be about $5.00 per tonne
- Trucking costs will vary between $10 and $20 per tonne depending on stand-by-time and distance traveled.

As illustrated in the following chart, it appears that there are seven (7) different routes that straw can take from the field to the plant gate.

Harvesting, Logistics and Storage Options



There are two alternative models for collecting bales from the field. Typically, this function is performed using either a tractor-powered or self-propelled bale collector. However, some operators load trucks directly in the field. This latter option can offer some cost savings, although it also presents higher risks in a wet year.

There are three choices available for storage of the straw, namely, end-of-field, district depot, or centralized storage. In dry conditions with good all-weather roads, end-of-field storage can be an attractive option. In wetter areas or districts without all-season road access, district depot or centralized storage may be a more desirable option due to the need to create a graded surface.

The **Harvesting and Logistics Costing Model** (Section 4.3) can be used to analyze the costs of each of the 7 options depending on the quality needs and volume of material to be assembled. The **Straw Production Model** (Section 4.1.1) can be used to assess the potential shrink associated with additional handling and transportation of employing depot storage. The model default assumption is that 3% of total mass is lost each time a bale is handled in the field and 5% for each time a bale is loaded-and-trucked (e.g. broken bales, wind loss, mechanical losses, etc.). Additional information about spoilage and shrinkage is presented in Section 4.2.3.

Storage losses through spoilage can range between 2% and 10% depending on the storage option employed (i.e. uncovered, tarp covering, indoor).

4.2.3 Spoilage/shrinkage – what percentage of spoilage should be accounted for relating to amount of time bales are sitting?

This section presents a discussion of the shrinkage associated with handling as well as the duration of storage. Estimates of the spoilage and shrinkage rates for material handling and storage duration will be provided.

Although there are different types of procurement systems, transportation and storage are part of all such systems. A summary of these systems and some storage cost estimates are provided in the Biomass Combined Heat and Power Catalogue of Technologies, see Appendix 5, page 9. This information

> *There are three common storage options for biomass feedstock: each option has its own benefits and challenges:*
>
> *1. Feedstock is hauled directly to the plant with no storage at the production site.*
> *2. Feedstock is stored at the production site and then transported to the plant as needed.*
> *3. Feedstock is stored at a collective storage facility and then transported to the plant from the intermediate storage location.*
>
> *The type of storage system used at the production site, intermediate site, or plant can greatly affect the cost and the quality of the fuel. Storage systems that maintain high fuel quality also cost the most. Typical storage systems, ranked from highest cost to lowest cost, include:*
>
> - *Enclosed structure with crushed rock floor ($10 to $15/ton)*
> - *Open structure with crushed rock floor ($6 to $8/ton)*
> - *Reusable tarp on crushed rock ($3/ton)*
> - *Outside unprotected on crushed rock ($1/ton)*
> - *Outside unprotected on ground ($0/ton)*

Note: These costs are presented as “typical” and, hence, we cannot make assumptions as to climatic conditions or soil profiles.

These storage costs are not the same but are similar to the costs outlined for the Chariton Valley Biomass Project presented in Section 4.1.6. The chart for the Chariton Valley Project indicates about 15% spoilage and shrinkage for switchgrass bales stored outside unprotected on a crushed rock base. Even the bales stored in enclosed sheds had 2% shrinkage.

As presented in the Secondary Information Review (Section 4.1.6, page 64), a PAMI report in 2002 indicates that spoilage losses can be as high as 40% in uncovered bales.

A paper presented by Blunk et al. *Quality and Property Changes in Rice Straw During Long Term Storage at the 2003 Annual Meeting of the American Society of Agricultural and Biological Engineers* indicated 40 to 60 % loss for fully uncovered bales.

Given this wide range of spoilage and shrinkage percentages it appears that a business using straw on a continuous schedule during the year should be prepared for a spoilage and shrinkage rate of up to 20 % (based on 40% for the year).

The costing model uses losses of 3% for handling, 5% for loading and 10% for storage.

4.2.4 In addition to alternative uses for the good straw, what are the possible uses for the waste straw? i.e.: cost/benefit for different uses such as incineration or composting.

It is difficult to define the concept of "waste straw". As illustrated in Section 4.2.1., feedstock materials that do not meet quality standards for the principle product, processing bi-products (e.g. flax shives), and residual products can be utilized in a number of different processes.

Moisture content, processing costs, and transportation costs become the limiting factor for implementing these alternative processing options. In addition, the cost-benefit of these options depends significantly on the local situation.

The highest value from these residual materials in most cases can be derived by producing heat either through direct incineration or processing into an intermediate product (e.g. fuel pellets, fuel cubes, fuel pucks) and transporting them to a location where there is a customer to consume the heat. Fuel cubes (approx. 7800 btu/lb) were approximately $80/ton this past winter.[50] While there is only one industrial straw pellet facility in Europe (pellets produced for CHP plant) and therefore no real trade in straw pellets the price of wheat straw pellets in Europe in 2006 were estimated at 120 – 140 Euro/tonne. Estimations of straw pellet production costs in Europe in 2006 reach from 90 to 160 €/t (based on a straw price of 25 – 60 €/t)[51]

Alternatively, composting offers the potential to create a soil amendment that can add nutrients and tilth to the soil. Composting offers a good alternative use for high moisture-content crop residues, because the process works best at between 50 to 70% moisture content. However, the resulting materials are fairly low in density, so the ability to ship large volumes over significant distances is limited.

There is also a horticultural and retail market for bagged compost. Entering this market will require investment in bagging facilities and developing wholesale / retail business relationship.

Agriculture Canada, Manitoba Agriculture and several universities have conducted a significant amount of applied research for composting systems over the years. To produce effective compost, it is necessary to obtain a balance between carbon ("browns"), nitrogen ("greens"), water and air inputs. Achieving the best mix is more an art gained through experience than an exact science. The ideal ratio approaches 25 parts

browns to 1 part greens (judge the amounts roughly equal by weight). Too much carbon will cause the pile to break down too slowly, while too much nitrogen can cause odor. The carbon provides energy for the microbes, and the nitrogen provides protein. http://www.compostguide.com/ .

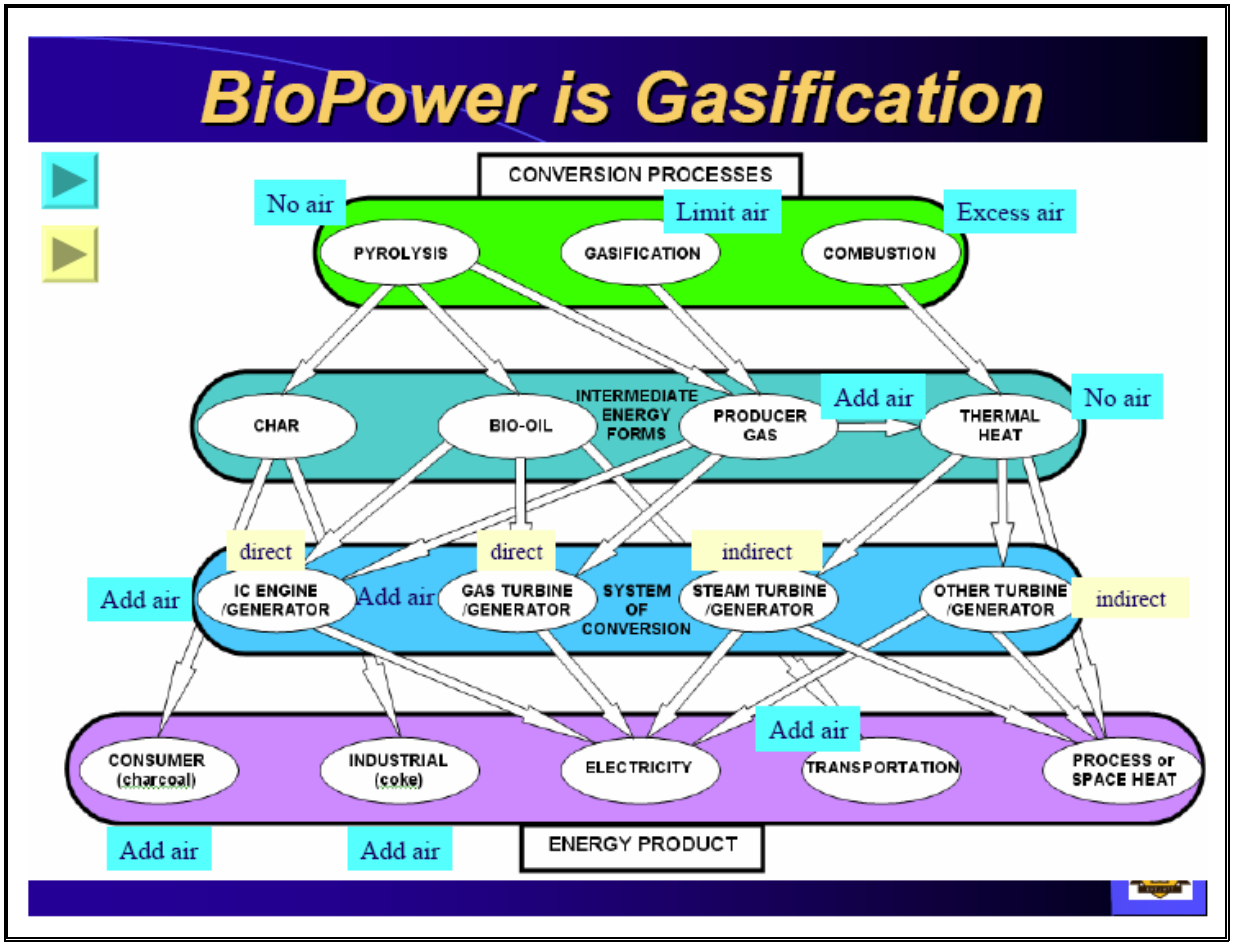
It is also possible to implement a composting system in conjunction with livestock production and processing operations. Manure, fallen stock and processing waste materials can be used as a nitrogen input in the process. Dr. Catherine Buckley of the Brandon Research Station of Agriculture Canada has been one of the leading researchers in Manitoba on this topic.
http://www.engormix.com/composting_hog_manure_%E2%80%93_e_articles_102_POR.htm

Depending on the source of feedstock materials, it may be necessary to secure environmental and other permits (e.g. water and air quality) from the Government in order to implement a composting operation. Some of these regulations are in the process of being amended, so business planners should contact Manitoba Conservation to seek guidance on regulatory standards.

4.2.5 Research and information on different burners and other technologies that may have potential to use biomass such as baled straw as an energy supply. Must look at not only potential energy produced, but also distribution and disposal of bi-products produced i.e.: large amount of ash

In this section the Study provides a profile of the conversion processes, highlights some of the combustion and gasification options being investigated/implemented in Manitoba, and also provides an overview of the technology that is being utilized in Denmark. On-going work at the University of Manitoba, Dr. Eric Bibeau (Manitoba Hydro/NSERC Alternative Energy Chair) and supported by Manitoba Hydro, which is assessing alternative energy opportunities for various biomass fuels, provides an excellent base for further work in this area. Extensive investigative work in this area is also occurring at EERC in Grand Forks. This Study does not provide a detailed analysis of the various combustion and gasification options as this is beyond the scope of this Study.

Bibeau, in his presentation on Gasification Myths, breaks the conversion processes into pyrolysis, gasification and combustion processes.



The report on "Biomass Combined Heat and Power Catalogue of Technologies", Appendix 5, provides an excellent overview of biomass conversion technologies including the following:

"biomass conversion refers to the process of converting biomass into energy that will in turn be used to generate electricity and/or heat. The principal categories of biomass conversion technologies for power and heat production are ***direct-fired*** and ***gasification*** systems. Within the direct-fired category, specific technologies include stoker boilers, fluidized bed boilers, and co-firing. Within the gasification category, specific technologies include fixed bed gasifiers and fluidized bed gasifiers."

"Biomass power systems are typically below 50 MW in size, compared to coal-fired plants, which are in the 100- to 1,000-MW range. Most of today's biomass power plants are ***direct-fired systems.*** The biomass fuel is burned in a boiler to produce high-pressure steam that is used to power a steam turbine-driven power generator. In many applications, steam is extracted from the turbine at medium pressures and temperatures and is used for process heat, space heating, or space cooling. ***Co-firing*** involves

substituting biomass for a portion of the coal in an existing power plant boiler. It is the most economic near-term option for introducing new biomass power generation. Because much of the existing power plant equipment can be used without major modifications, co-firing is far less expensive than building a new biomass power plant. Compared to the coal it replaces, biomass reduces SO2, NOX, CO2, and other air emissions.

Biomass ***gasification*** systems operate by heating biomass in an environment where the solid biomass breaks down to form a flammable gas. The gas produced—synthesis gas, or syngas—can be cleaned, filtered, and then burned in a gas turbine in simple or combined-cycle mode, comparable to LFG or biogas produced from an anaerobic digester. In smaller systems, the syngas can be fired in reciprocating engines, microturbines, Stirling engines, or fuel cells."

The following Table provides a summary of biomass conversion technologies for producing heat and power. This Table includes a summary of the common fuel types. It should be noted that most of the biomass conversion technology has been focused on wood residue products such as sawdust, bark, chips and hog fuel rather than agriculture residues such as straw.

Biomass Conversion Technology	**Common Fuel Types**	**Feed Size**	**Moisture Content**	**Capacity Range**
Stoker grate, under-fire stoker boilers	Sawdust, bark, chips, hog fuel, shavings, end cuts, sander dust	0.25–2 in.	10–50%	4 to 300 MW (many in the 20 to 50 MW range)
Fluidized bed boiler	Wood residue, peat, wide variety of fuels	< 2 in.	< 60%	Up to 300 MW (many in the 20 to 25 MW range)
Co-firing—pulverized coal boilers	Sawdust, bark, shavings, sander dust	< 0.25 in.	< 25%	Up to 1000 MW
Co-firing—stoker, fluidized bed boilers	Sawdust, bark, shavings, hog fuel	< 2 in.	10–50%	Up to 300 MW
Fixed bed gasifier	Chipped wood or hog fuel, rice hulls, shells, sewage sludge	0.25–4 in.	< 20%	Up to 50 MW
Fluidized bed gasifier	Most wood and agriculture residues	0.25–2 in.	15–30%	Up to 25 MW

Source: Based on Wright, 2006. [53]

In assessing the various technologies an important consideration is the state of the technology. Direct fired systems have been in operation for many years and the technology is to a large extent "proven" whereas the gasification systems should be viewed as emerging technology. The following tables identify "the major biomass conversion technologies and associated prime mover technologies for CHP applications. The commercial status of each technology for biomass applications is described." Appendix 5

Energy Conversion Technology	Conversion Technology Commercialization Status	Integrated CHP Technology (Prime Mover)	Prime Mover Commercialization Status
Anaerobic Digestion			
Anaerobic digester (from animal feeding operations or wastewater treatment facilities)	Commercial technology	Internal combustion engine	Commercial technology
		Microturbine	Commercial technology
		Gas turbine	Commercial technology
		Fuel cell	Commercial introduction
		Stirling engine	Emerging
Direct Combustion—Boilers			
Fixed bed boilers (stoker)	Commercial technology – Stoker boilers have long been a standard technology for biomass as well as coal, and are offered by a number of manufacturers.	Steam turbine	Commercial technology
Fluidized bed boilers	Commercial technology – Until recently fluidized bed boiler use has been more widespread in Europe than the United States. Fluidized bed boilers are a newer technology, but are commercially available through a number of manufacturers, many of whom are European-based.		
Cofiring	Commercial technology – Cofiring biomass with coal has been successful in a wide range of boiler types including cyclone, stoker, pulverized coal, and bubbling and circulating fluidized bed boilers.		
Modular* direct combustion technology	Commercial technology – Small boiler systems commercially available for space heating. A small number of demonstration projects in CHP configuration.	Small steam turbine	Commercial technology
		Organic Rankine cycle	Emerging technology – Some "commercial" products available.
		"Entropic" cycle	Research and development (R&D) status
		Hot air turbine	R&D status

*Small, packaged, pre-engineered systems (smaller than 5 MW).

Energy Conversion Technology	Conversion Technology Commercialization Status	Integrated CHP Technology (Prime Mover)	Prime Mover Commercialization Status
Gasification			
Fixed bed gasifiers	Emerging technology – The actual number of biomass gasification systems in operation worldwide is unknown, but is estimated to be below 25. A review of gasifier manufacturers in Europe, USA, and Canada identified 50 manufacturers offering commercial gasification plants from which 75 percent of the designs were fixed bed; 20 percent of the designs were fluidized bed systems.	Gas turbines – simple cycle	Prime movers have been commercially proven with natural gas and some medium heating value biogas. Operation on low heating value biogas and the effects of impurities on prime mover reliability and longevity need to be demonstrated.
Fluidized bed gasifiers		Gas turbines – combined cycle	
		Large internal combustion (IC) engines	
Modular* gasification technology	Emerging technology – A small number of demonstration projects supported with research, design, and development funding.	IC engine	Commercial technology – But operation on very low heating value biogas needs to be demonstrated.
		Microturbine	
		Fuel cell	Commercial introduction
		Stirling engine	Emerging technology
Modular* hybrid gasification/combustion	Emerging technology – Limited commercial demonstration.	Small steam turbine	Commercial technology – But integrated system emerging.

*Small, packaged, pre-engineered systems (smaller than 5 MW).

Denmark – Utilization of Straw in Combined Heat and Power

As indicated in 4.1.4 Denmark is a leading country in the utilization of straw for biomass to energy applications. Manitoba can benefit from the lessons learned. There are a number of different burners (boilers) which are being used in Denmark for the combustion of straw in their power plants. The following tables provide information on selected parameters for 11 of these straw fired power plants. In addition to this information from Denmark the Study highlights boilers that are utilizing straw in other parts of the world. The reference for the information from Denmark has been provided as Appendix 6 which provides a detailed description of the technological improvements that have occurred over the past 19 years. Among the main concerns in utilizing straw in combustion is the high content of alkali chloride in straw which leads to high risk for corrosion and fouling in the boiler. It is worth noting that improvements in technology are on-going and in 2009 a new straw fired boiler will be commissioned at Fynsvaerket, Denmark. This new power plant will use 170,000 tonnes or 2.5 PJ straw per year.

Selected Parameters for 11 Straw Fired Power Plants in Denmark

Plant		Haslev CHP	Slagelse CHP	Rudkøbing CHP	Grenaa CHP	Måbjerg CHP	Masnedø CHP
Start of operation	year	1989	1990	1990	1992	1993	1996
Steam temperature	°C	455	450	450	505	520	522
Steam pressure	bar	67	67	60	92	92	92
Electrical power	MW_{net}	5	11.4 [1]	2.6	17.9	28 [2]	9
Electrical efficiency (net.)	%	23	24	22	22		25
Firing system		Cigarburner	Shredder + Stokerscrew on reciprocating grate	Shredder + Stokerscrew on vibrating grate	CFB (Co-firing max. 60% straw)	Cigarburner	Shredder + Stokerscrew on vibrating grate
Fluegas cleaning		Bagfilter	Electrostatic filter	Bagfilter	Electrostatic filter	Bagfilter	Bagfilter
Boiler manufactor		Vølund	Aalborg Boilers	B&W Energi	Foster Wheeler	Vølund	B&W Energi

[1] Includes steam from waste incineration plant

[2] Includes steam from 2 waste incineration boilers and the biomass boiler (max. 27%)

Plant		Ensted 3 biomassplant	Maribo/Saks-købing CHP	Avedøre 2 biomassplant	Studstrup 3/4	Amager 2
Start of operation	year	1998	2000	2001	2002/2005	2003
Steam temperature	°C	510 (design 542)	542	540 (design 583)	540	450
Steam pressure	bar	210	92	310	250	93
Electrical power	MW_{net}	38	11.3	50	350	20
Electrical efficiency (net.)	%	41	29	48	41	27
Firing system		Straw: Shredder + Stokerscrew on vibrating grate, Wood Chips: Spreaderstoker	Shredder + Stokerscrew on vibrating grate	Shredder + Stokerscrew on vibrating grate	PF boiler (Co-firing max. 10% straw)	PF boiler (100% straw)
Fluegas cleaning		Electrostatic filter	Bagfilter	Bagfilter	Electrostatic filter	Electrostatic filter
Boiler manufactor		B&W Energi	FLS miljø [3]	Vølund	Babcock 1984	Steinmüller 1972

[3] FLS miljø is former B&W Energi, today the company is Bioener

Other Examples

Elean Power Plant[54], Ely, UK

- Straw-burning power plant with installed capacity of 38 MW and utilizes 200,000 tonnes annually.
- Shreds the straw bales and feeds loose straw into the furnace. [55]
- Plant specifically designed to burn wheat straw and the handling, storage, processing and burning was designed specifically for straw.[56]

Sulzbach-Rosenberg, Bavaria, Germany

- Operating since 1995
- 4.2 MW el. CHP plant, Maximum fuel used 15 tpd biomass
- Two lines, one fed by agricultural residues, silviculture residues and energy crops and the other by wood residues.
- Both lines connected to single steam cycle generating steam
- Agriculture and silviculture biomass supplied by a community group established for that purpose. Approximately 300 people belong to this group which is responsible for producing, harvesting, storing and delivering.[57]

Manitoba Combustion Systems

There are a variety of combustion systems operating in Manitoba mostly operating on coal as a fuel. There are approximately 13 Blue Flame Stoker systems. These are larger, higher end systems. The majority of units operated by the Hutterite Colonies (70) are smaller underfed rotary grate stokers. These range in size from about .5 million BTU/hr to 5 – 10 million BTU/hr. Prairie Bioenergy has started to produce biomass cubes for use in these systems. The auger size (need 6" or bigger) can sometimes be a problem when using biomass cubes as a fuel. (Appendix 2).

Vidir Biomass – Biomass Energy System Technologies

- Vidir Biomass Inc., headquarters in Arborg, Manitoba
- Utilizes their *VIDIR BEST* system featuring an updraft, atmospheric pressure heating system.
- The system uses straw or wood chips which is combusted on a grate.
- A conveyor or blower system is used to feed the fuel automatically over the grate.
- Separate from the combustion unit is a water boiler which receives heat from the combustion unit. The hot water in the boiler is than available for hot water heating. *"A computerized control system synchronizes and automates the rate of biomass feed, the amount of combustion air intake and the temperature difference in inlet and outlet water temperature"*.
- The VIDIR BEST system is underdevelopment and the company is working to design systems that will utilize straw[58]

Issues in the Straw to Heat and Power Systems

Moisture content of feedstock - an important factor in the biomass conversion process is the moisture content of the feedstock material. "For all biomass conversion technologies, the lower the as-fired moisture content of the biomass feedstock, the higher the energy efficiency of the conversion process. If moisture is part of the fuel, then this moisture must be heated and vaporized and this energy is lost in the stack. In direct-fired conversion processes each additional 10 percent of moisture in the fuel lowers the conversion (or boiler) efficiency by about 2 percentage points. Therefore, as-received biomass with moisture contents of 30 to 50 percent, results in process efficiencies of 6 to 10 percentage points lower than bone dry feedstock." Appendix 5

Ash - Ash is one of, if not the main challenge in the combustion of straw for heat and power. Straw tends to be high in alkali chlorides (potassium or chlorine) which can lead to "unmanageable ash deposition problems on heat exchange and ash-handling surfaces". Appendix 5 Chlorine in combustion gases, particularly at high temperatures, can cause accelerated corrosion of combustion system and flue gas cleanup components. Potassium ash content is relatively high in fresh wood, green particles, and fast-growing biomass, which causes the ash to melt at low temperatures and leads to a tendency for fouling and slagging. Appendix 5. Various technologies such as soot blowing are being integrated into systems to lesson this problem. The slagging and corrosion can be reduced through temperature control, co-firing, and using fuel additives, but still remains a significant barrier to straw combustion. Adjusting boiler temperatures can slow the adverse chemical reactions, but might conflict with temperatures required for efficient combustion and heat transfer.[59] The type of combustion unit is a major factor in the resulting ash quality and how that ash can be utilized. Appendix 5

Ash Disposal

The disposal of bottom ash and fly ash can present a serious problem to biomass to heat and power operations. Following are a few possible uses for this by product:

- ***Cement and concrete*** - fly ash from coal-fired power plants can be used in the production of cement and concrete. However this is not the case with ash from straw combustion processes as there is a limit regarding the amount that can be used in cement and concrete (10%).
- ***Returning to the land*** - Returning ashes to the location where the straw was produced is one option that is being used. As long as the ash does not present soil fertility problems this is one very attractive option. This type of ash recycling is happening in countries such as Sweden, Austria, Germany and Denmark. These countries have established legislation that enable and controls the recycling of biomass ashes. Often these ashes are high in heavy metals and there is a limit to the amount that you can return to the land.[60] One of the ways that this is being handled in countries such as Austria and Germany is that when producers deliver biomass to a plant they are committed to taking so much ash back with them to put on their land.
- ***Utilization as Building Material*** – bottom ashes from fluidized bed combustion or gasification contains mostly sand and can replace other sand like material in road construction or landscaping. Fly ash is a very fine material and not suitable for this application.

- ***Utilization as a fuel-*** utilization as a fuel is possible for fly ash when the carbon content is high enough (35% by wt) or the calorific value is higher than 15 MJ/kg. The problem with this application is the transport of the ash. This may be dealt with by converting the ash into pellets, logs or briquettes so that it can be transported and used as a fuel. [61]
- ***Landfill*** – in Denmark for the year 2000 approximately 27,700 tons of ash was produced of which approximately 20,000 was distributed in agriculture and forestry and 7,000 tons were put in landfills.[62]
- ***Greenhouse operations*** – Prairie Bioenergy is currently doing some testing of the components of ash and the suitability of using ash in greenhouse operations (Appendix 2)

4.2.6 Pelleting or other options of unusable straw for fuel.

For straw that cannot be used for fuel, there remains two potential uses, namely for livestock or for nutrients.

Livestock uses could include bedding or establishing a base in feedlots.

For nutrients, the straw could be reapplied to the land (similar to solid manure) or composted. Composting does add cost to the process, but it carries the benefit of increasing the density of the resulting materials.

4.3.1 Conduct an in-depth cost of baling analysis to include the entire straw procurement operation including the purchase of straw, baling, stacking, transportation, storage, and all administration costs of different types of straw.

In Section 4.2.?, we reported that the cost of purchasing straw will vary quite significantly across different regions of Manitoba and from year-to-year. A small minority of producers surveyed value the crop residues at $5 or less per tonne in the swath. Most placed a maximum value of $25 for this feedstock material in the swath l

- **Payment in the Swath – Between $5.00 and $25 per tonne**

The cost of the harvesting, collection/stacking, storage and transportation of the crop residues has been modeled based on input from MAFRI's Custom Rates Guidelines for 2006 http://www.gov.mb.ca/agriculture/financial/custom2007/index.html .

The costs presented in this section represent a base case of end-of-field storage. Four alternative baling systems are presented, namely round, small cube, medium cube, and large square bales. This version of the analysis assumes the bales are covered with a tarp

at the end of the field. Please see Section 4.1.6 for a discussion of the cost-benefit analysis of alternative storage systems.

In this report, the base-case operation are modeled as a dedicated custom harvesting fleet where harvesting and collection occurs over a 60 – 90 day window and the loading and trucking operates on a year-round basis. As a result, it is assumed in the base case that harvesting and handling equipment is **utilized at a rate of 600 hours per year**. Lower annual utilization rates of equipment will result in increased cost per tonne handled.

We have not attempted to model the cost of alternative harvesting systems such as loafing or forage handling systems because we could not identify an operational example of that model of logistics management While some "desk-research" studies have suggested that these operational models have the potential to reduce logistics costs, they have not been proven in full-scale field operation to date.

Harvest and Handling Costs - Custom Round Bales

Approach: MB Ag Custom Rates

Assumptions

Bale Weight	900	lb	0.4082	tonnes/bale
Baler Capacity	15	bales/hr	6.1236	tonnes/hr
Twine/Wrap	$0.35	$/bale	$0.86	$/tonne
Collection Capacity	35	bales/hr	14.2884	tonnes/hr
Avg. Trucking Distance	30	miles	48.2700	km
Number Bales/Load	40	bales	16.3296	tonnes
Loading Time	45	minutes		
Round Trip Duration	2	hr		
Implied Truck Standby	46%			
Loader Stand-by	40%			

ITEM		RATE	MEASURE	PER BALE	PER TONNE	EXPLANATION
Havesting/Baling				**$5.18**	**$12.68**	
	Baler	$18.41	per hour	$1.23	$3.01	6 x 5 ft, 600 hr/yr
	Twine/Wrap	$0.50	per bale	$0.50	$1.22	16,000 foot plastic twine
	Tractor	$51.74	per hour	$3.45	$8.45	140 hp 2 WD, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	included in tractor custom rate @ $10 / hr
Collection				**$1.76**	**$4.30**	
	Wagon/Picker	$9.71	per hour	$0.28	$0.68	
	Tractor	$51.74	per hour	$1.48	$3.62	140 hp 2 WD, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	included in tractor custom rate @ $10 / hr
Storage				**$2.86**	**$7.00**	
	Shelter	$1.50	per tonne	$0.61	$1.50	tarp
	Labour	$0.50	per tonne	$0.20	$0.50	installing tarp
	Site Upgrade/Rent	$5.00	per tonne	$2.04	$5.00	crushed rock base Section 4.1.6
Transportation / Trucking				**$5.54**	**$13.58**	
	Loading/Unloading	$77.17	per day	$0.89	$2.19	
	Travel	$1.83	per km	$4.42	$10.82	
	Labour Travel	$0.00	per hour	$0.00	$0.00	
	Labour Standby	$10.00	per hour	$0.23	$0.57	
Loading Costs				**$1.52**	**$3.72**	
	Tractor FWA	$62.12	per hour	$1.16	$2.85	160 hp FWA 600 hr per year
	Front-end Loader	$7.92	per hour	$0.15	$0.36	
	Snow Clearing	$0.50	per tonne	$0.20	$0.50	
	Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE				**$16.85**	**$41.28**	

Harvest and Handling Costs - Custom Medium Cube Bales (3 x 3)

Approach: MB Ag Custom Rates

Assumptions

Bale Weight	650	lb	0.2948	tonnes/bale	
Baler Capacity	45	bales/hr	13.2678	tonnes/hr	
Twine/Wrap	$1.00	$/bale	$3.39	$/tonne	
Collection Capacity	40	bales/hr	11.7936	tonnes/hr	
Avg. Trucking Distance	30	miles	48.2700	km	
Number Bales/Load	55	bales	16.2162	tonnes	need to consider weight restrictions
Loading Time	40	minutes			
Round Trip Duration	1.5	hr			
Implied Truck Standby	28%				
Loader Stand-by	40%				

ITEM	RATE	MEASURE	PER BALE	PER TONNE	EXPLANATION
Havesting/Baling			**$2.95**	**$10.01**	
Baler	$51.21	per hour	$1.14	$3.86	30 x 35 in, 90,000 cap cost
Twine/Wrap	$0.50	per bale	$0.50	$1.70	
Tractor	$59.09	per hour	$1.31	$4.45	160 hp 2 WD
Labour		per hour	$0.00	$0.00	
Collection			**$1.72**	**$5.83**	
Wagon/Picker	$9.71	per hour	$0.24	$0.82	est based on round bale
Tractor	$59.09	per hour	$1.48	$5.01	160 hp 2 WD
Labour		per hour	$0.00	$0.00	
Storage			**$1.11**	**$3.75**	
Shelter	$3.00	per tonne	$0.88	$3.00	assume double tarping (fall and spring)
Labour	$0.50	per tonne	$0.15	$0.50	
Site Upgrade/Rent	$0.25	per tonne	$0.07	$0.25	
Transportation / Trucking			**$3.69**	**$12.51**	
Loading/Unloading	$77.17	per day	$0.40	$1.36	
Travel	$1.83	per km	$3.21	$10.89	
Labour Travel	$0.00	per hour	$0.00	$0.00	
Labour Standby	$10.00	per hour	$0.08	$0.26	
Loading Costs			**$1.00**	**$3.38**	
Tractor FWA	$62.12	per hour	$0.75	$2.55	155 hp, FWA
Front-end Loader	$7.92	per hour	$0.10	$0.33	
Snow Clearing	$0.50	per tonne	$0.15	$0.50	
Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE			**$10.46**	**$35.49**	

Harvest and Handling Costs - Large Square Bales (3 x 4)					
Approach: MB Ag Custom Rates					
Assumptions					
Bale Weight	1000	lb	0.4536	tonnes/bale	
Baler Capacity	40	bales/hr	18.1440	tonnes/hr	
Twine/Wrap	$1.00	$/bale	$2.20	$/tonne	
Collection Capacity	45	bales/hr	20.4120	tonnes/hr	
Avg. Trucking Distance	30	miles	48.2700	km	
Number Bales/Load	40	bales	18.1440	tonnes	need to consider weight restrictions
Loading Time	35	minutes			
Round Trip Duration	1.5	hr			
Implied Truck Standby	28%				
Loader Stand-by	40%				
ITEM	**RATE**	**MEASURE**	**PER BALE**	**PER TONNE**	**EXPLANATION**
Havesting/Baling			**$3.44**	**$7.58**	
Baler	$58.42	per hour	$1.46	$3.22	$110,000 captial price
Twine/Wrap	$0.50	per bale	$0.50	$1.10	
Tractor	$59.09	per hour	$1.48	$3.26	160 hp 2WD
Labour	$0.00	per hour	$0.00	$0.00	
Collection			**$1.39**	**$3.07**	
Wagon/Picker	$9.71	per hour	$0.22	$0.48	
Tractor	$52.95	per hour	$1.18	$2.59	140 hp 2WD
Labour	$0.00	per hour	$0.00	$0.00	
Storage			**$3.18**	**$7.00**	
Shelter	$1.50	per tonne	$0.68	$1.50	
Labour	$0.50	per tonne	$0.23	$0.50	
Site Upgrade/Rent	$5.00	per tonne	$2.27	$5.00	pole shed, crushed Rock
Transportation / Trucking			**$5.07**	**$11.18**	
Loading/Unloading	$77.17	per day	$0.55	$1.21	
Travel	$1.83	per km	$4.42	$9.74	
Labour Travel	$0.00	per hour	$0.00	$0.00	
Labour Standby	$10.00	per hour	$0.11	$0.24	
Loading Costs			**$1.25**	**$2.75**	
Tractor FWA	$62.12	per hour	$0.91	$2.00	
Front-end Loader	$7.92	per hour	$0.12	$0.25	155 hp, FWA
Snow Clearing	$0.50	per tonne	$0.23	$0.50	
Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE			**$14.33**	**$31.58**	

Harvest and Handling Costs - Very Large Square Bales (4 x 4)						
Approach: MB Ag Custom Rates						
Assumptions						
	Bale Weight	1200	lb	0.5443	tonnes/bale	
	Baler Capacity	40	bales/hr	21.7728	tonnes/hr	
	Twine/Wrap	$1.00	$/bale	$1.84	$/tonne	
	Collection Capacity	50	bales/hr	27.2160	tonnes/hr	
	Avg. Trucking Distance	30	miles	48.2700	km	
	Number Bales/Load	40	bales	21.7728	tonnes	need to consider hieght and weight res
	Loading Time	20	minutes			
	Round Trip Duration	1.5	hr			
	Implied Truck Standby	28%				
	Loader Stand-by	40%				
ITEM		**RATE**	**MEASURE**	**PER BALE**	**PER TONNE**	**EXPLANATION**
Havesting/Baling				**$3.68**	**$6.77**	
	Baler	$68.28	per hour	$1.71	$3.14	4 x 4 ft, $120,000 new, 600 hr/yr
	Twine/Wrap	$0.50	per bale	$0.50	$0.92	
	Tractor	$59.09	per hour	$1.48	$2.71	160 hp, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	
Collection				**$1.38**	**$2.53**	
	Wagon/Picker	$9.71	per hour	$0.19	$0.36	use round bale figures
	Tractor	$59.09	per hour	$1.18	$2.17	160 hp, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	
Storage				**$4.08**	**$7.50**	
	Shelter	$1.50	per tonne	$0.82	$1.50	
	Labour	$1.00	per tonne	$0.54	$1.00	
	Site Upgrade/Rent	$5.00	per tonne	$2.72	$5.00	pole shed, crushed rock
Transportation / Trucking				**$5.07**	**$9.32**	
	Loading/Unloading	$77.17	per day	$0.55	$1.01	
	Travel	$1.83	per km	$4.42	$8.11	
	Labour Travel	$0.00	per hour	$0.00	$0.00	
	Labour Standby	$10.00	per hour	$0.11	$0.20	
Loading Costs				**$0.92**	**$1.69**	
	Tractor FWA	$62.12	per hour	$0.52	$0.95	150 hp FWA, 600 hr/yr
	Front-end Loader	$15.64	per hour	$0.13	$0.24	
	Snow Clearing	$0.50	per tonne	$0.27	$0.50	
	Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE				**$15.14**	**$27.81**	

Overall, the harvesting, collection, storage and transportation costs under this base case scenario range between $28 and $41 per tonne. Adding in the cost of the procurement of straw in the swath $5 to $25 per tonne), the expected cost FOB plant gate from this "base case scenario" could range from $33 to $66 per tonne.

4.3.2 Develop a cost analysis template that can be used for the analysis of a straw procurement operation of any size. The template should allow a sensitivity analysis to be conducted to show the affect on bale price when various tonnages are baled.

The Logistics Costing Analysis template enables the user to model any size of crop residuals operation. The user can specify over 20 input cost-drivers ranging from annual utilization rates for equipment to assumptions about harvesting capacity and trucking distance.

The volume of materials required by a processing operation does not have a significant impact on the cost of procurement once volumes exceed 10,000 to 20,000 tonnes per year. At these or higher levels of production, it is possible to utilize all of the harvesting, collection and trucking fleet at high levels of annual utilization and thus minimize total costs.

The one cost variable that will increase with volume of material assembled is the trucking costs. As higher volumes of feedstock materials need to be assembled, the average trucking distance, and thus trucking costs, will increase on a per tonne basis.

4.3.3 Complete a productivity analysis taking into account changing weather and crop production variables, i.e. affect on costs when drought or excess moisture causes reduced straw production.

As reported in Section 4.1.1, the volume of crop residues varies significantly from one year to the next. These variations are driven by a number of factors including the total acres planted to each crop, the weather conditions, and the number of operators who are willing to contract for supply of their resources.

Excess moisture and drought conditions present a significant operational and business risk for any agricultural residue processing operation. For example, 2005 was the year of the "big wet" when a lot of crop acres in Manitoba could not be seeded due to wet conditions. As a result, the potential biomass crop was reduced by 25% to 35% on a provincial basis and much more in local areas.

From previous regional analysis, we also know that drought years can have a comparable impact on the potential volume of biomass materials, particularly in the south-western area of the province.

During a wet year, a processing operation would be challenged to expand the harvesting and logistics footprint and incur increased trucking expenses. During a dry year, costs could be increased due to lower throughput of the harvesting equipment as well as trucking expenses.

Effective business planning of any crop residue operation should include modeling a minimum, maximum, average, average + 1 Standard Deviation, and average -1 Standard Deviation in scenario analysis. The key challenge is to answer "*how will we operate" under typical operating conditions (i.e. average +/- 1 Standard Deviation) versus how will we operate in an exceptional year*".

For some types of processing operations, it may be more "productive" to idle the operation for a period of time instead of expand the harvesting and collection footprint during exceptional years.

4.3.4 Determine the cash flow requirements for a seasonal baling business where the operation is conducted from August until December and the majority of cash expenses are accrued during this period.

The cash flow requirements of the harvesting and straw logistics handling system have the following elements:

- field baling, collection and storage operations
- transportation and central storage (if applicable) operations
- quality control and contracting management
- administration and management

Field baling, collection and storage activities will occur over a 60 to 90 day period in most years (i.e. August to October). It is also assumed that the producer will want payment during this season upon receipt of the product.

The remaining cost elements are assumed to occur at a constant level throughout the year. The following chart provides three illustrative examples of possible cash flow patterns.

Cost Element		Small	Medium	Large	
	Cost Detail	20,000	200,000	500,000	
Producer Payment		$300,000	$3,000,000	$7,500,000	
Field Operations		$479,600	$3,168,000	$8,875,000	
Transporation Operations		$346,000	$3,918,000	$6,965,000	
Quality Control and Contract Operations		$17,380	$173,800	$347,600	
Adminstration and General Management		$17,500	$175,000	$350,000	
Fiancing Costs		$28,140	$353,010	$816,900	
Total Annual Operating Costs		$1,188,620	$10,434,800	$24,037,600	
Cash Flow					Cumlative
	Q1 (Jan-Mar)	$34,085	$384,984	$706,625	$706,625
	Q2 (Apr-Jun)	$34,085	$384,984	$706,625	$1,413,250
	Q3 (Jul-Sep)	$813,685	$6,552,984	$17,081,625	$18,494,875
	Q4 (Oct- Dec)	$353,818	$2,496,984	$6,623,292	$25,118,167

Note: Details on the annual operating costs are discussed in Section 4.3.5.

4.3.5 Determine the financing options for storage and purchase of fibre and present payment models.

Section 4.3.11 explores financing options and payment models in some detail. Overall, there appears to be three alternative models for organizing the ownership of feedstock materials, namely:

- Company purchases straw in the swath and has ownership of it throughout the logistics system
- Farmer retains ownership of the straw and is paid for it upon delivery to one of the following
  - end-of-field stack
  - district depot yard
  - central storage site
- One or more intermediary companies purchase the straw from the farmer, harvest it, collect it and deliver it to a plant on a seasonal or just-in-time basis.

One method to minimize financing costs is to delay incurring the loading and trucking costs associated with moving the product to the processing plant. The chart on the next page provides illustrative examples of financing costs for three different types of operation. This financing calculator is included as part of the harvesting and logistics costing model.

Overall, the feedstock inventory financing adds about $1.50 per tonne to the cost of acquired materials.

The user of the model should also consider other financing costs, such as financing required for land and buildings, start-up financing costs, and an inventory reserve financing cost. The 2001 SW Fibre Co-op study (Appendix 1) reports the following financing costs for an 800,000 ton / year intermediary operation (e.g. a straw co-op).

Financing Costs

Producer Advance

Harvest Cost per ton (round)			$ 15.73	
In-the-Swath Payment			$14.00	
Total Producer Advance			$19,323,489	
Interest Cost @	**9%**		**$869,557**	

Inventory Reserve

Reserve Level			235,000	tons
Harvest Cost	$ 15.23	/ ton	$3,578,908	- assume square bales
In-the-Swath Payment	$14.00	/ton	$3,290,000	
Storage Cost @	**$ 15.13**	/ ton	$3,555,102	- assumes pole shed
Total Cost			$10,424,010	
Interest Cost @	**9%**		**$938,161**	

Total Annual Interest Cost	**$1,807,718**	
Total Capital Financing		$29,747,499

Size of Operation			In-Swath Cost	Baling, Collecting and Field Storage	Trucking and Loading Costs	In-Swath Cost	Baling, Collecting and Field Storage	Trucking and Loading Costs	Total	
		Tonnes	$15.00	per tonne	per tone					
Small	round	20,000	$15.00	$23.98	$17.30	$300,000	$479,600	$346,000	$1,125,600	
Medium	med cube	200,000	$15.00	$15.84	$19.59	$3,000,000	$3,168,000	$3,918,000	$10,086,000	
Large	large sq	500,000	$15.00	$17.75	$13.93	$7,500,000	$8,875,000	$6,965,000	$23,340,000	
						Raw Material Inventory Financing Costs (1/2 year)				
	Financing Assumption			Interest Rate		In-Swath Cost	Collecting and Field Storage	Trucking and Loading Costs	Total Financing Cost	Cost/ Tonne
Small	assume FCC financing for farmer			5%		$7,500	$11,990	$8,650	$28,140	$1.41
Medium	assume Intermediary finance at FCC			7%		$105,000	$110,880	$137,130	$353,010	$1.77
Large	assume BBB corporate rate for Company			7%		$262,500	$310,625	$243,775	$816,900	$1.63

4.3.6 Conduct a cost comparison of using 4x4x8 large square bales vs. large round bales.

The Costing and Logistics Model enables the user to compare the relative cost of using four different baling systems, namely, large round bales, medium cube bales, large cube bales and very large cube bales. Overall, there is a clear relationship between the level of capital intensity (i.e. capital cost of equipment) and decreasing cost per tonne.

The analysis conducted for the base case scenario indicates that as long as equipment resources are utilized at a high-level, then logistics costs per tonne can be decreased by migrating toward a more expensive fleet of equipment.

Comparison of Logistics Costs		
Harvesting Method	Baling Costs (per tonne)	Cost FOB Plant Gate (per tonne)
Large Round Bale	$12.68	$41.28
Medium Cube Bale	$10.01	$35.49
Large Cube Bale	$7.68	$31.68
Very Large Cube Bale	$6.77	$27.81

A critical variable in this analysis is the user's assumption about the capacity of the baling operation. In heavy crops, it is probable that large balers will have a significant cost advantage (i.e. the base case scenario). Under lighter crop conditions, this cost advantage may decrease somewhat.

4.3.7 Identify and evaluate alternative handling methods other than baling, i.e. provide an overview of other methods such as stacking or piling and chopping vs. baling.

This section provides an identification and preliminary evaluation of alternative methods for handling straw. Baling is the most prevalent system currently being used but other systems have been used extensively in the past and other systems are being evaluated.

In a presentation by Shahab Sokhansanj of ORNL, the loafing and ensiling systems were compared to the baling system.[63] The following pictures illustrate the methods of removing the straw from the field, grinding it and loading it into trucks to be moved to a processing plant. These systems recognize that the straw eventually has to be ground at some point in the process and they utilize high capacity trucks to move the ground material to the processing plant.

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System 1 - baling

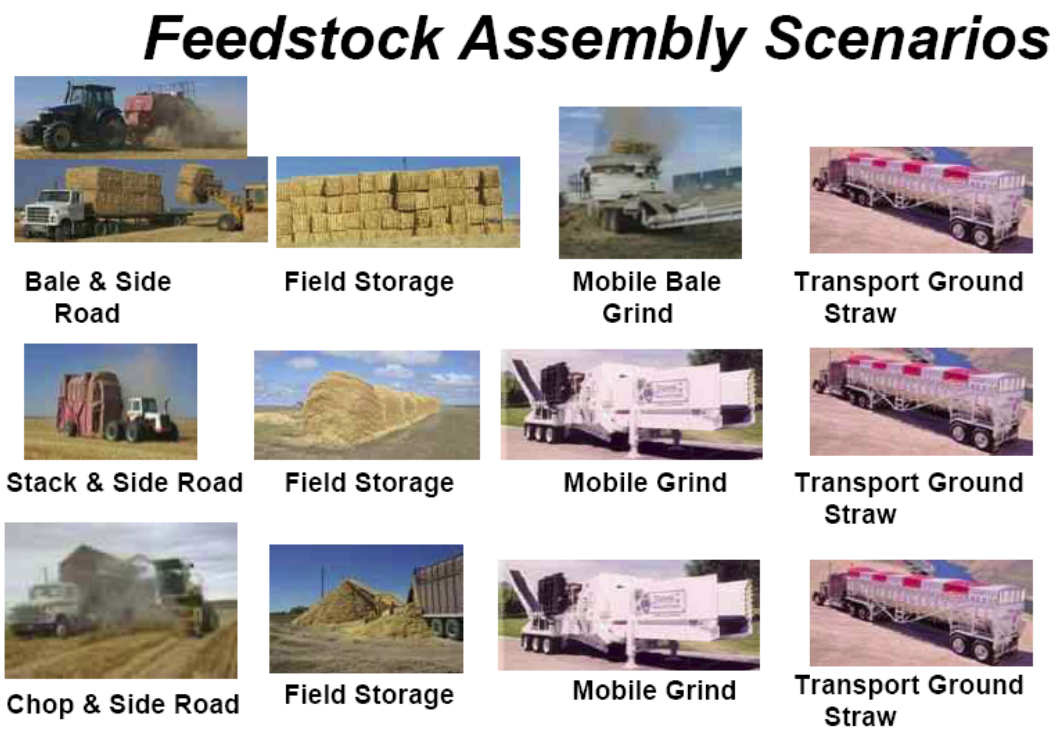
System 2 - loafing

System 3 - ensiling

In his presentation comparing these systems, Sokhansanj indicates that the Integrated Biomass Supply Analysis and Logistics model shows that:

- It is feasible to assemble a low cost supply system for biomass at a much reduced cost ($31-37/dt) than the existing baling system ($53/dt)
- The loafing system costs roughly 40 % less than baling and 30% less than ensiling
- The ensiling system is an attractive option but the cost of concrete silo bunkers increases the overall costs
- Energy input to the collection and supply system is 2-4% of the energy content of the biomass
- Carbon emissions from ensiling systems are high due to highly powered self-propelled forage harvesters and trucks.

Further information is provided in a presentation at the DOE/USDA Biomass Feedstock Gate Review Meeting March 15, 2005 by Duane R. Grant.[64]



McLeod Harvester

In the promotional material for the McLeod Harvest system it is stated that it increases profits, reduces herbicide use, controls volunteer growth, reduces hay and silage requirements and saves time and labour.

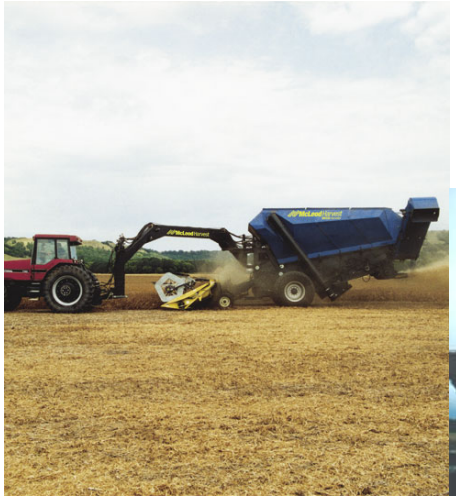
Description of the McLeod Harvest system:

- The McLeod Harvester uses a direct-cut or pick-up header to collect the crop. The conventional cylinder threshes the crop, efficiently separating the grain, chaff and weed seed, collectively called graff, from the straw. Only straw is returned to the field. It can be chopped and spread by the straw chopper or dropped into a swath for baling.
- The harvester has an 800-bushel tank to accommodate the large amount of material being handled. When the tank is full, the graff is unloaded into a waiting truck. The harvester can unload 800-bushels in less than three minutes.
- The truck takes the graff to the McLeod Harvest mill set up near the grain bins. The truck is fitted with a silage-type end gate to dump the load of graff onto the mill's receiving deck.
- The truck driver uses a remote control to start up the engine and lower the receiving deck to receive the new load. The receiving deck automatically feeds the material into the mill.
- The mill is completely automatic. While the truck driver goes back for another load, the clean grain exits into a hopper for the grain auger that takes it to the grain bin. The remaining crop residue, now called millings, are crushed by the mill's exit fan, then

blown out into a pile to be stored as a nutritious livestock feed -- a valuable second product of the harvest.

- The millings are blown through a tube and discharged to a convenient location up to 230 feet from the mill. Cattle can feed directly from the millings pile. The millings pile forms a crust that sheds water and prevents wind scatter while retaining its nutrient value. From a crop that averages 40-bushels per acre, the millings from 1100 acres have the approximate feed value of 700 round bales of hay.

Harvesting



Unloading

Cleaning

World Wide Interest

Research into harvesting, pelleting and densification of biomass is taking place in various parts of the world. In a presentation at the 2001 Annual Meeting of the American Association of Agricultural and Biological Engineers, P.D. Gupta of the Division of Farm Machinery and Post Harvest Technology of Indian Grassland and Fodder Research Institute, (IGFRI) Jhansi, U.P., India discussed the activities of that Institute. It “has developed good machines like Tractor Operated Flail Mower, Tractor Operated Rotary Disc Mower, Power Operated Feed Pelleting Machine and Power Operated Densifying Machine. These machines have been tested at IGFRI Central Research Farm in large scale and found suitable for popularisation. The Flail Mower performs the jobs of

harvesting, chaffing and blowing of grasses and sorghum fodder in to the accompanying trailer with out - put capacity of 0.3 ha/hr. The Rotary Disc Mower is driven by PTO shaft of 45 hp tractor for berseem harvesting with out put capacity of 0.25 ha/hr. Feed Pelleting machine is operated by 5 hp electric motor used for making feed pellets of crop residue, wheat bhusa, fodder leaves with or without concentrate at a capacity of 60-80 kg/hr. The dia. of feed pellets can be varied from 5 mm to 40 mm with length of 2.5 to 12 cm. Forage Densifying Machine stationary type operated by 25 hp electric motor is used for baling of grasses with and without berseem and wheat bhusa by mixing molasses . The out put capacity of the machine is 600 to 800 kg/hr with bale density of 400-450 kg/m3.

The combination of these machines like (i) fodder harvesting, drying and pelleting and (ii) Forage grass harvesting and their baling by value addition can solve the problem of fodder deficit during lean period. The surplus crop residues and forage material can be processed stored safely and transported easily to distant places economically due to higher density."[65]

4.3.8 Cost analysis to include purchasing/leasing equipment vs. hiring out as custom work.

With assumptions about equivalent labour costs and utilization rates for equipment, there should be negligible difference between purchasing/leasing equipment versus hiring out as custom work. Both models need to recover the total cost of ownership and operation and, thus, both models experience equivalent cost drivers.

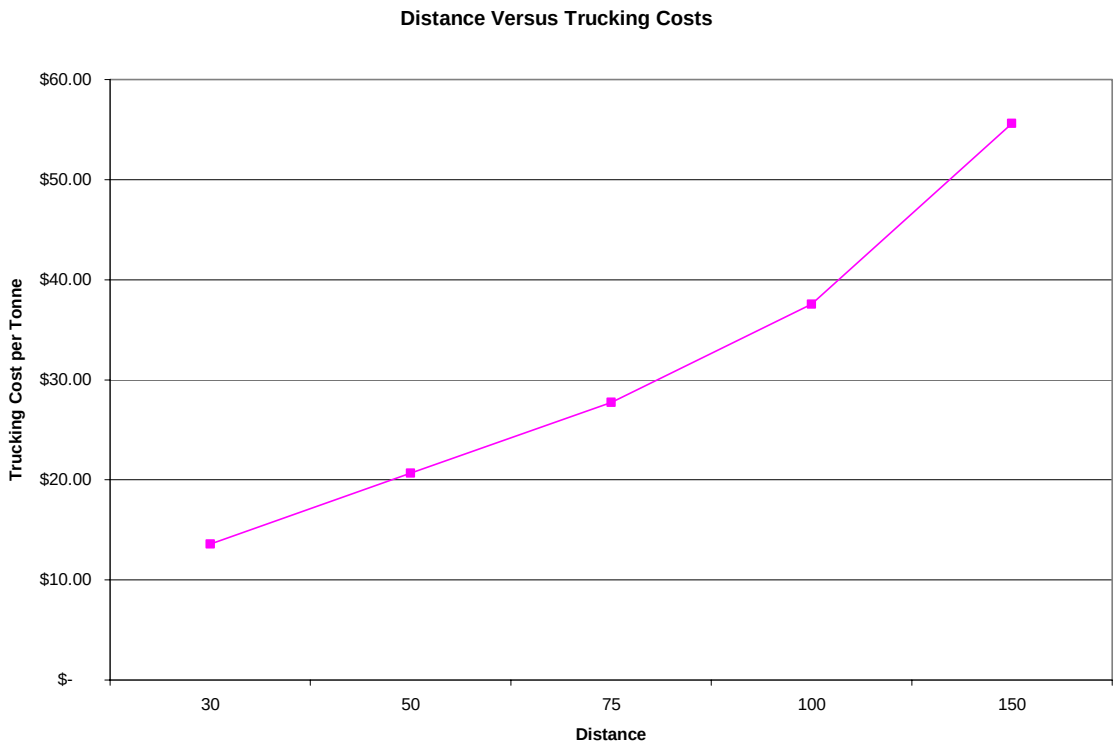
Hiring out the work to a custom harvesting operation could be more cost effective if that organization extends its season by also harvesting forage for other markets. This model of operation should reduce logistics costs per tonne assuming there is a competitive market for custom harvesting services.

There may be, however, a significant difference between assuming custom operations versus "producer operated" harvesting equipment. A significant proportion of the harvesting fleet in Manitoba is under-utilized compared to its potential capacity. It may be possible for small processing operations to capitalize on this existing fixed investment in equipment and lower their marginal operating costs.

4.3.9 Transportation costs for 50 and 75 mile radius of main storage site.

The logistics analysis model enables the user to specify input assumptions for any size of logistics footprint and trucking model for each of the 4 types of harvesting options.

The following chart provides an illustrative example of the relationship between trucking distance and trucking cost.



4.3.10 Analysis of storage options

4.3.10.1 Optimum Volume of Storage at Plant

In most situations, centralized storage of straw at the processing plant location will be the most expensive logistics handling model. Loading and trucking the straw to a plant costs between $15 and $30 per tonne. Assembling the straw at a centralized storage will require this cost to be financed for between 25% and 50% of a full year. As such, employing centralized storage could increase the per-tonne cost by between $0.40 and $1.50 per tonne.

Some companies with demanding input quality standards may choose to employ centralized storage in order to gain better control over input quality levels and to reduce spoilage and shrinkage. This cost-benefit will need to be assessed for each individual venture.

If a Company chooses to employ a “just-in-time” inventory management model, they still will want to consider the size of a buffer inventory to deal with shocks in the supply chain. For example, winter storms could disrupt shipments for several days. Similarly, spring weight restrictions could either increase the trucking costs or reduce the supply capacity of the trucking fleet. In most cases a buffer inventory representing a 1 to 2

month supply of feedstock materials should be adequate to deal with these supply chain risks.

4.3.11 Forecasts should be made for potential of increased cost of inputs i.e. fuel, supplies, labour, equipment, etc.

The Logistics Costing Model enables the user to select input costs for each major line item (e.g. cost of equipment, operating costs, fuel costs, labour costs, etc.). As a result, the user can elect to either run sensitivity analysis (i.e. vary one input variable at a time and measure the impact on logistics costs) or run scenario analysis (i.e. vary multiple input variables at a time according to a defined "future scenario").

The following charts provide an illustrative example of a scenario analysis that was run for large square bales.

	Total Large Square Cost FOB Plant				
Sensitivity Scenario	Equipment (Fixed Cost)	Operating Cost	Labour	Fuel	Annual Utilization
+ 50%	$33.64	$33.66	$32.71	$32.27	$34.09
+ 20%	$32.77	$32.79	$32.17	$32.59	$32.63
Base Case	**$31.91**	**$31.91**	**$31.91**	**$31.91**	**$31.91**
- 25%	$31.04	$31.03	$31.51	$31.22	$31.47
-50%	$30.18	$30.15	$31.11	$30.54	$31.18

	Total Large Square Sensitivity Cost Analsyis				
Sensitivity Scenario	Equipment (Fixed Cost)	Operating Cost	Labour	Fuel	Annual Utilization
+ 50%	5%	5%	3%	1%	7%
+ 20%	3%	3%	1%	2%	2%
Base Case	0%	0%	0%	0%	0%
- 25%	-3%	-3%	-1%	-2%	-1%
-50%	-5%	-6%	-3%	-4%	-2%

Overall, it appears that logistics costs are most sensitive to the annual utilization rate of equipment and equipment capital costs. Lower utilization rates or higher equipment capital costs could increase logistics costs by the most percentage.

4.3.12 Analysis of straw purchase models

The Terms of Reference call for an analysis of the following straw purchase models:

- Company purchase and storage of all straw
- Company purchase with deposit and financing options
- Farmer storing straw on-farm, bearing total cost, with financing required.

There is a fourth option that has been explored in Manitoba and other jurisdictions, namely establishing one or more intermediary entities that take responsibility for the harvesting, collection and delivery of the product to a company on a just-in-time basis. Conceptually, these entities could be organized as investor-owned companies, membership-based co-operatives, or a company-owned subsidiary. One of the potential advantages of this purchasing and operating model is that equipment and labour assets can be employed in other lines of business when they are not required for the harvesting of straw.

The selection of the desirable purchasing model for a processing operation could be affected by a number of factors, including the:

- Choice of baling option and operating method
- Quality management and control needs
- Volume of straw required
- Choice of storage option (centralized, depot, end-of-field)
- Financing and insurance costs (farmer, custom operator / co-op, company); and
- Availability of forward advance payments.

The choice of the desired *baling option* (round, cube, large square) *and operating method* (farm-owned, custom-operator, company owned) could affect the purchasing model. For a company wanting to purchase round-bales that are harvested from farmers, it is possible that farmer harvesting and storage of the straw could be desirable, particularly for processors requiring less than 50,000 tonnes per year. Employing a custom-harvester or company-owned fleet would fit better with company purchase and storage of the straw.

It is possible that company purchase and storage of the straw could provide increased company control over *quality management and control practices*. Quality factors such as moisture content, consistency, purity and protection from the elements could be directly managed by the company to satisfy their specific needs.

Companies requiring large volumes of straw (i.e. 500,000 or more tonnes per year) will most likely have to rely, at least in part, on hiring custom operated fleets or operating their own fleet of harvesting and collection equipment. In this situation, the farmer will tend to want to be paid a price for the straw in the swath upon the company taking possession of it in the field. If a custom harvesting service is employed, they too will want payment upon delivery of their services.

The *choice of storage model* (i.e. end-of-field, depot, centralized) may also affect the desired payment method. It is possible that farm-harvested and collected straw that is stored at the end of the farmer's field could be available for a deposit and financing. Most farmers will desire full payment for their straw and all services provided by them before the straw leaves their property.

Financing and insurance costs could also play a role in selecting a payment model. If farmers can access lower-cost financing and crop-insurance through government-backed organizations, there may be a cost advantage for employing farmer ownership of the inventory. It was also noted previously in this report that farmer's may be able to access lower cost insurance for bales stored on their land than custom operators or companies. Similarly, if a Forward Advance Payments Program is established for crop residues, farmers may gain access to low cost or zero-cost financing for the inventory.

Each company and processing operation will need to assess their specific feedstock supply needs and business structures to identify a purchasing model that will be effective.

4.3.13 Environmental cost/benefit analysis (removal of straw versus incorporation into the soil).

Section 4.1.1 above provides information about the total straw production in Manitoba on an area basis. The soil conservation needs are addressed in Section 4.1.3 with an estimate of 1 tonne/ha (890 lb./acre) of residue as an adequate level of residue that should remain for conservation purposes. In Section 4.1.3 reference is provided as to the importance of the roots and stubble in maintaining soil carbon and nitrogen.

If straw is removed from cropland, then, of course, the nutrients in the straw are removed. Information provided by Heard et al. in their 2001 study, *Nutrient Loss of Straw Removal or Burning in Manitoba*, (See Appendix 1, page 71) provides a range of these dollar values for nutrients removed. These ranges in nutrient value lost per acre were $11.15 to 16.25 for wheat straw, $6.70 to 18.65 for oat straw and $4.05 to 7.35 for flax straw. These dollar values were based on Year 2001 values of nitrogen at $0.29 per pound, phosphorus at $0.27 per pound, potassium at $0.14 per pound and sulphur at $0.24 per pound. This calculation was based on the removal of 1 tonne of wheat straw per acre, 1 tonne of oat straw per acre and 0.5 tonne of flax straw per acre.

Since 2001 fertilizer prices have increased significantly and, hence, such dollar value estimates of nutrient value lost per acre have increased accordingly. Reports of current prices of nitrogen at $0.59 to 0.98 per pound and phosphorus at $0.83 per pound would suggest that the 2001 values should be doubled at the least. Hence, for 2008 values these estimates of nutrient value lost per acre would be $22.30 to 32.50 for wheat straw, $13.40 to 37.30 for oat straw and $8.10 to 14.70 for flax straw.

If the straw were not removed but incorporated or spread then the costs of the associated field operations would be incurred by the producer. Certainly, with expenses of such

items as fuel, repairs and depreciation these costs would be significant. Factors such as type of farming practice and the type of soil would affect the calculation of such costs.

4.3.14 Regulatory – Fire prevention considerations, Rodent control, road access such as height restrictions

Regulations pertaining to transporting straw have a direct affect on the amount of straw that can be moved and therefore the cost of moving straw. As well regulations pertaining to fire prevention and rodent control must be taken into consideration as they can have a direct affect on straw storage and transportation.

Transportation Regulations
The main transportation regulations pertaining to vehicle weights and dimensions can be found on the website "Vehicle Weights and Dimensions on Classes of Highways Regulation" ***http://web2.gov.mb.ca/laws/regs/pdf/h060-575.88.pdf*****.** The following charts provide information on various vehicle classifications pertaining to highway classifications (http://www.gov.mb.ca/mit/transreg/compreg/wdcompguide.html) :

RTAC Truck

diagram (Illustration showing how RTAC truck measurements are determined)

Parameters	Limit		
Overall Length	Max. 12.5 m		
Overall Width	Max. 2.6 m		
Overall Height	Max. 4.15 m		
Box Length	not controlled		
Wheelbase	not controlled		
Effective Rear Overhang	Max. 4.0 m		
Interaxle Spacings			
Steering Axle to Drive Axle	Min. 3.0 m		
Weights			
Axle Weights	RTAC	A1	B1
Steering Axle	7300 kg	7300 kg	7300 kg
Single Axle	9100 kg	9100 kg	8200 kg
Tandem Axle	17000 kg	16000 kg	14500 kg
Maximum Gross Combination Weights			

Axles	RTAC	A1	B1
2 Axles	16400 kg	16400 kg	15500 kg
3 Axles	24300 kg	23300 kg	21800 kg
Note: The use of a tridem axle on a truck is prohibited.			

RTAC Truck & Pony Tailer

diagram (Illustration showing how RTAC truck & pony trailer measurements are determined)

Parameters	Limit		
Overall Length	Max. 23 m		
Overall Width	Max. 2.6 m		
Overall Height	Max. 4.15 m		
Box Length	Max. 20.0m		
Truck			
Length	Max. 12.5 m		
Wheelbase	not controlled		
Hitch Offset	Max. 1.8 m		
Pony Trailer *			
Length	Max. 12.5 m		
Wheelbase	Min. 6.5 m		
Track Width	Min. 2.5 m / Max. 2.6 m		
Effective Rear Overhang	Max. 4.0 m		
Interaxle Spacings			
Steering Axle to Drive Axle	Min. 3.0 m		
Single Axle to Single, Tandem or Tridem	Min. 3.0 m **		
Tandem Axle to Tandem Axle	Min. 5.0 m		
Tandem Axle to Tridem Axle	Min. 5.5 m		
Weights			
Axle Weights	RTAC	A1	B1
Steering Axle	7300 kg	7300 kg	7300 kg
Single Axle	9100 kg	9100 kg	8200 kg
Tandem Axle	17000 kg	16000 kg	14500 kg

Tridem Axle (Trailer) Axle spread 2.4m - 2.5m	21000 kg	21000 kg	20000 kg
Maximum Gross Combination Weights			
Axles	RTAC	A1	B1
3 Axles	25500 kg	25500 kg	23700 kg
4 Axles	33400 kg	32400 kg	30000 kg
5 Axles	41300 kg	39300 kg	36300 kg
6 Axles	45300 kg	44300 kg	41800 kg

* Pony trailers with Gross Vehicle Weight Rating of less than 10,000 kg. do not qualify as RTAC units.

** This minimum applies to the interaxle spacing between adjacent axle units of a truck in combination with a pony trailer.

RTAC Truck & Full Trailer

diagram (Illustration showing how RTAC Truck and Full Trailer are measured)

Parameters	Limit
Overall Length	Max. 23 m
Overall Width	Max. 2.6 m
Overall Height	Max. 4.15 m
Box Length	Max. 20.0m
Truck	
Length	Max. 12.5 m
Wheelbase	not controlled
Hitch Offset	Max. 1.8 m
Full Trailer *	
Length	Max. 12.5 m
Wheelbase	Min. 6.5 m
Track Width	Min. 2.5 m / Max. 2.6 m **
the use of a Converter Dolly is not permitted on this combination ***	
Interaxle Spacings	
Steering Axle to Drive Axle	Min. 3.0 m

Single Axle to Single or Tandem	Min. 3.0 m ****		
Tandem Axle to Tandem Axle	Min. 5.0 m		
Tandem Axle to Tridem Axle	Min. 5.5 m		
Weights			
Axle Weights	RTAC	A1	B1
Steering Axle	7300 kg	7300 kg	7300 kg
Single Axle	9100 kg	9100 kg	8200 kg
Tandem Axle	17000 kg	16000 kg	14500 kg
Tridem Axle (Trailer):			
Axle spread 2.4 m - < 3.0 m	17000 kg	17000 kg	16400 kg
Axle spread 3.0 m - < 3.6 m	24000 kg	24000 kg	22700 kg
Axle spread 3.6 m - 3.7 m	31000 kg	31000 kg	29000 kg
Sum of Axle Weights of Full Trailer			
4 Axle Truck and Trailer Combination	17000 kg	17000 kg	16400 kg
6 Axle Truck and Trailer Combination	24000 kg	24000 kg	22700 kg
7 Axle Truck and Trailer Combination	31000 kg	31000 kg	29000 kg
8 Axle Truck and Trailer Combination	------- not fully controlled -------		
Maximum Gross Combination Weights			
Axles	RTAC	A1	B1
4 Axles	33400 kg	33400 kg	31900 kg
5 Axles	41300 kg	40300 kg	38200 kg
6 Axles	48300 kg	47300 kg	44500 kg
7 Axles	55300 kg	54300 kg	47630 kg
8 Axles	62500 kg	56500 kg	47630 k

* A maximum of 2 axle units in contact with the ground on the full trailer.

** Full trailers manufactured prior to July 1, 1988 that have not had their running gear totally replaced may have a track width of < 2.5 m.

*** The use of a trailer converter dolly equipped with a tridem axle unit is not permitted.

**** This minimum applies to the interaxle spacing between adjacent axle units of a truck in combination with a full trailer.

Custom operators (Appendix 2) are well aware of the height and width regulations pertaining to straw movement on Manitoba roads and highways and have developed methods of loading straw in order to maximize the amount on the load. Issues identified as a concern in moving straw in rural Manitoba included:

- Rural roads are not designed for truck traffic and are too soft.
- Bridge restrictions can cause problems
- Road approaches are too narrow for maneuvering large trucks.

Rodent Control

There are no specific regulations governing the control of rodents in straw storage areas or straw storage facilities. If the Department of Health received complaints they may request that something be done to rectify a problem (Appendix 2). Manitoba Environmental Assessment and Licensing would require a company to put forward a Rodent Control Plan as part of the application for an Environmental License. This Plan would then be reviewed and the plan would be either approved or conditions placed on it as necessary (Appendix 2). Given the straw situation at the former Dow/Isobord Plant in Elie there will likely be public concerns with regard to what might happen with regard to potential rodent problems (Appendix 2).

Isobord Particle Board License 1998

http://www.gov.mb.ca/conservation/eal/archive/1998/licences/1911s2.html

This is the link to the ISOBORD ENTERPRISES INC – Particle Board Plant license that was issued in 1998. There does not appear to be any mention of rodent control in this license however a license issued now for such a plant would require a rodent control plan.

Fire Prevention Considerations and Regulations

While there appear not to be any specific fire regulations with regard to how straw is stored outdoors, it would probably fall under Fire Code Section 2.4 as a combustible material. It would need to be stored in a manner so as to not cause an undue fire hazard. A business considering establishment and wanting to store large volumes of straw outdoors would need to submit their plans to the Fire Chief of the local municipal authority. The local municipal authority could place conditions on how the straw is stored.

Straw stored indoors may require a permit and also the building in which it is stored may require a sprinkler system depending on the size of the building (Appendix 2).

5.0 Business Case Scenarios

Based on the information presented in the Secondary Information Review and input from the Project Steering Committee and the Bio-Products Advisory Working Group, the fibres of focus and possible business scenarios were identified. In this Section, for each of the Business Case Scenarios, the Study provides; a brief description, an indication of the size and the logistics footprint, a description of the type of bales used and the feedstock procurement system. For each scenario a chart is included providing an illustrative example of the logistics costs associated with this type of processing operation.

5.1 Small Biomass Heat or Pelleting/Cubing System

A small biomass heating system, combined heat and power, or pelleting/cubing/etc. system could require between 10,000 and 50,000 tonnes of feedstock materials per year.

The logistics footprint for this type of procurement system will vary depending on the location in the province. In high production regions, sufficient feedstock materials could be accessed within 20 to 30 miles. In low production regions, the footprint would need to be expanded.

Given the limited volumes of materials to be purchased, the Company will most likely need to purchase round bales unless there is a custom operator that offers a square baling service in the area.

The chart on the following page provides an illustrative example of the logistics costs associated with this type of processing operation

Harvest and Handling Costs - Custom Round Bales						
Approach: MB Ag Custom Rates						
Assumptions						
	Bale Weight	900	lb	0.4082	tonnes/bale	
	Baler Capacity	15	bales/hr	6.1236	tonnes/hr	
	Twine/Wrap	$0.35	$/bale	$0.86	$/tonne	
	Collection Capacity	35	bales/hr	14.2884	tonnes/hr	
	Avg. Trucking Distance	30	miles	48.2700	km	
	Number Bales/Load	40	bales	16.3296	tonnes	need to consider safety restrictions
	Loading Time	45	minutes			
	Round Trip Duration	2	hr			
	Implied Truck Standby	46%				
	Loader Stand-by	40%				
ITEM		**RATE**	**MEASURE**	**PER BALE**	**PER TONNE**	**EXPLANATION**
Havesting/Baling				**$5.18**	**$12.68**	
	Baler	$18.41	per hour	$1.23	$3.01	6 x 5 ft, 600 hr/yr
	Twine/Wrap	$0.50	per bale	$0.50	$1.22	16,000 foot plastic twine
	Tractor	$51.74	per hour	$3.45	$8.45	140 hp 2 WD, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	included in tractor custom rate @ $10 / hr
Collection				**$1.76**	**$4.30**	
	Wagon/Picker	$9.71	per hour	$0.28	$0.68	
	Tractor	$51.74	per hour	$1.48	$3.62	140 hp 2 WD, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	included in tractor custom rate @ $10 / hr
Storage				**$2.86**	**$7.00**	
	Shelter	$1.50	per tonne	$0.61	$1.50	tarp
	Labour	$0.50	per tonne	$0.20	$0.50	installing tarp
	Site Upgrade/Rent	$5.00	per tonne	$2.04	$5.00	crushed rock base Section 4.1.6
Transportation / Trucking				**$5.54**	**$13.58**	
	Loading/Unloading	$77.17	per day	$0.89	$2.19	
	Travel	$1.83	per km	$4.42	$10.82	
	Labour Travel	$0.00	per hour	$0.00	$0.00	
	Labour Standby	$10.00	per hour	$0.23	$0.57	
Loading Costs				**$1.52**	**$3.72**	
	Tractor FWA	$62.12	per hour	$1.16	$2.85	160 hp FWA 600 hr per year
	Front-end Loader	$7.92	per hour	$0.15	$0.36	
	Snow Clearing	$0.50	per tonne	$0.20	$0.50	
	Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE				**$16.85**	**$41.28**	

5.1.2 Medium-Sized Processing Venture – e.g. Fibre / Pulp Production

A medium-sized crop residue venture could take the form of a fibre processing venture that converts flax or other straw into input products for fibre production or pulp and paper

production. In the longer term, it is also possible that this size of venture could emerge to produce combined heat and power at a utility-scale of operation.

Based on our analysis of the production data as well as the primary research, it appears that most to all of the available flax fibre is already being processed in Manitoba. Our primary research indicates that the current company is even importing feedstock materials from Saskatchewan.

[Ed Note: The client may want to modify this business case scenario to focus on non-flax processing options.]

A 50,000 to 200,000 tonne processing operation will most likely need to secure the feedstock materials over a distance ranging from 50 to 75 miles. It is also assumed at this scale of operation, a cube baling system provided by custom operators or a company owned fleet will be employed. The chart on the next page provides an illustrative example of the logistics costing for this type of operation.

Harvest and Handling Costs - Custom Medium Cube Bales (3 x 3)

Approach: MB Ag Custom Rates

Assumptions

Bale Weight	650	lb	0.2948	tonnes/bale	
Baler Capacity	45	bales/hr	13.2678	tonnes/hr	
Twine/Wrap	$1.00	$/bale	$3.39	$/tonne	
Collection Capacity	40	bales/hr	11.7936	tonnes/hr	
Avg. Trucking Distance	50	miles	80.4500	km	
Number Bales/Load	55	bales	16.2162	tonnes	need to consider weight restrictions
Loading Time	40	minutes			
Round Trip Duration	3	hr			
Implied Truck Standby	40%				
Loader Stand-by	40%				

ITEM		RATE	MEASURE	PER BALE	PER TONNE	EXPLANATION
Havesting/Baling				**$2.95**	**$10.01**	
	Baler	$51.21	per hour	$1.14	$3.86	30 x 35 in, 90,000 cap cost
	Twine/Wrap	$0.50	per bale	$0.50	$1.70	
	Tractor	$59.09	per hour	$1.31	$4.45	160 hp 2 WD
	Labour		per hour	$0.00	$0.00	
Collection				**$1.72**	**$5.83**	
	Wagon/Picker	$9.71	per hour	$0.24	$0.82	est based on round bale
	Tractor	$59.09	per hour	$1.48	$5.01	160 hp 2 WD
	Labour		per hour	$0.00	$0.00	
Storage				**$1.11**	**$3.75**	
	Shelter	$3.00	per tonne	$0.88	$3.00	assume double tarping (fall and spring)
	Labour	$0.50	per tonne	$0.15	$0.50	
	Site Upgrade/Rent	$0.25	per tonne	$0.07	$0.25	
Transportation / Trucking				**$6.14**	**$20.83**	
	Loading/Unloading	$77.17	per day	$0.57	$1.92	
	Travel	$1.83	per km	$5.35	$18.16	
	Labour Travel	$0.00	per hour	$0.00	$0.00	
	Labour Standby	$10.00	per hour	$0.22	$0.75	
Loading Costs				**$1.00**	**$3.38**	
	Tractor FWA	$62.12	per hour	$0.75	$2.55	155 hp, FWA
	Front-end Loader	$7.92	per hour	$0.10	$0.33	
	Snow Clearing	$0.50	per tonne	$0.15	$0.50	
	Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE				**$12.91**	**$43.80**	

5.1.3 Large-Scale Processing Venture

This business case scenario assumes that the feedstock materials are used in a fibre-ethanol of other comparable industrial processing facility. The minimum size of this type of operation is assumed to be 500,000 tonnes per year.

Based on the production analysis, it appears that this type of operation may need to have a logistics footprint of between 75 miles and 150 miles, depending on its location in Manitoba.

It is assumed that this large volume operation would use a dedicated fleet of high capacity baling equipment.

The following chart provides an illustrative example of the logistics costs for this scenario.

Harvest and Handling Costs - Very Large Square Bales (4 x 4)						
Approach: MB Ag Custom Rates						
Assumptions						
	Bale Weight	1200	lb	0.5443	tonnes/bale	
	Baler Capacity	40	bales/hr	21.7728	tonnes/hr	
	Twine/Wrap	$1.00	$/bale	$1.84	$/tonne	
	Collection Capacity	50	bales/hr	27.2160	tonnes/hr	
	Avg. Trucking Distance	100	miles	160.9000	km	
	Number Bales/Load	40	bales	21.7728	tonnes	need to consider hieght and weight res
	Loading Time	20	minutes			
	Round Trip Duration	4.5	hr			
	Implied Truck Standby	21%				
	Loader Stand-by	40%				
ITEM		**RATE**	**MEASURE**	**PER BALE**	**PER TONNE**	**EXPLANATION**
Havesting/Baling				**$3.68**	**$6.77**	
	Baler	$68.28	per hour	$1.71	$3.14	4 x 4 ft, $120,000 new, 600 hr/yr
	Twine/Wrap	$0.50	per bale	$0.50	$0.92	
	Tractor	$59.09	per hour	$1.48	$2.71	160 hp, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	
Collection				**$1.38**	**$2.53**	
	Wagon/Picker	$9.71	per hour	$0.19	$0.36	use round bale figures
	Tractor	$59.09	per hour	$1.18	$2.17	160 hp, 600 hr/yr
	Labour	$0.00	per hour	$0.00	$0.00	
Storage				**$4.08**	**$7.50**	
	Shelter	$1.50	per tonne	$0.82	$1.50	
	Labour	$1.00	per tonne	$0.54	$1.00	
	Site Upgrade/Rent	$5.00	per tonne	$2.72	$5.00	pole shed, crushed rock
Transportation / Trucking				**$15.35**	**$28.20**	
	Loading/Unloading	$77.17	per day	$0.40	$0.73	
	Travel	$1.83	per km	$14.72	$27.05	
	Labour Travel	$0.00	per hour	$0.00	$0.00	
	Labour Standby	$10.00	per hour	$0.23	$0.42	
Loading Costs				**$0.92**	**$1.69**	
	Tractor FWA	$62.12	per hour	$0.52	$0.95	150 hp FWA, 600 hr/yr
	Front-end Loader	$15.64	per hour	$0.13	$0.24	
	Snow Clearing	$0.50	per tonne	$0.27	$0.50	
	Labour Standby	$0.00	per hour	$0.00	$0.00	
TOTAL FOB PLANT GATE				**$25.41**	**$46.69**	