Assessment of Business Case for Purpose-Grown Biomass in Ontario

Prepared for
Ontario Federation of Agriculture
Erie Innovation and Commercialization

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Acknowledgements

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Clear and precise economic information on biomass production is offered to Ontario's innovative farming communities using the known reference point of established cash crops such as hay, soybean, grain corn and winter wheat. Biomass production introduces a new industrial value chain that could benefit individual farmers, communities, and co-operatives in rural Ontario.

The economic model for energy crops (miscanthus, switchgrass, tall grass prairies, and sorghum) includes the variable and fixed cost expenditures, yield, revenue and margins. The model is used with the best currently available information, but information for specific individual farm situations can be substituted to obtain local economic plans.

Biomass is presently not price competitive with coal and natural gas. However, in local markets, biomass is less than half the cost ($/GJ) of heating oil and propane, which now supply a large portion of rural Ontario. Large energy utilities are currently best served by coal or natural gas, but agricultural biomass export opportunities are possible in the near term due to European demand for biomass fuels.

It is our hope that this report meets the need of Ontario's agricultural producers as Canada and the world seek renewable and carbon neutral energy sources that help to meet the energy and environmental demands of the 21st century.

We also appreciate the many contributions from Stephen Duff and John Molenhuis, both of OMAFRA; Peter Sykanda, OFA; Don Nott, Nott Farms; Scott Abercrombie, Gildale Farms; Jake Lozon, Rural Lambton Stewardship Network; Om Dangi, Agriculture Environmental Renewal Canada; Dean Tiessen, New Energy Farms; Ian Moncrieff, Canadian Biofuel Inc.; Ralph Spaans, Ontario Ministry of Natural Resources; Gord Surgeoner, Ontario Agri-Food Technologies; Lovleen Bassan, Ontario Power Generation; Khirshid Saharan and Ted Pidgeon, Agriculture and Agri-Food Canada; Members of the Business Case Working Group; Members of Steering Committee for Agricultural Biomass for Combustion Energy; AGRIS Co-operative Ltd.; Ontario Federation of Agriculture; Agriculture and Agri-Food Canada; and John Kabel, Katherine Albion, Mary Prendiville, Caroline Craig, Pat Kelley, Joel Adams of Western University Research Park, Sarnia-Lambton Campus.

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Preface

In 2010, Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA) and Ontario Power Generation (OPG) formed a stakeholder steering committee to address a policy directive of the Ontario government to cease using coal to generate electricity by the end of 2014. Prior to the Steering Committee being established, OPG had decided to operate the Atikokan plant with forest-generated biomass and was considering co-firing natural gas and agricultural biomass at the Nanticoke and Lambton plants.

With the opportunity of having Ontario farmers supply hundreds of thousand tonnes of biomass, the OMAFRA–OPG Steering Committee established three working groups; a group to examine agronomic issues with respect to purpose-grown biomass, a technology group to assess value chain processes to prepare biomass for combustion and a business group to develop a business case that would ultimately guide public policy on pricing and investment. Dr. John Kelly of Erie Innovation and Commercialization (Ontario Fruit and Vegetable Growers' Association) was selected to lead the economic task team.

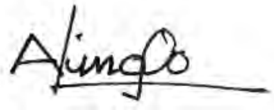
In parallel to these efforts, the Ontario Federation of Agriculture (OFA) received Agriculture Agri-Food Canada funding through the Agricultural Adaptation Council to conduct producer level research and value chain determination. In an earlier study, the OFA examined the opportunities to use biomass as a substitution fuel for coal and natural gas.

Based on work in progress, it was jointly decided to develop a Business Case with all the resources available in Ontario. Accordingly, the OFA facilitated the process by engaging Dr. Aung Oo of the Sarnia Research Park to develop the Business Case. His work was supported by Dr. John Kelly as chair of the Business Case Working Group, Charles Lalonde, the Ontario Soil and Crop Association, producers, aggregators and the OFA.

The business case study in this report is presented in a modular form in order to provide benchmark information to any value chain stakeholder. Specifically, the costs and revenues are assembled to mimic the various processes of a value chain beginning with the production, aggregation, end use for regional and provincial combustion markets and for export. Finally, the comparative advantage of biomass is compared to various fuel sources.

The authors remind readers that the costs and revenue numbers presented in this report reflect early stages of a value chain development, and numbers should be tailored to individual users. As the biomass economy matures, there will be opportunities to improve these projections. In the meantime, the report is as robust as possible and can be used for business planning as well as for public policy determination.

Finally, the authors wish to thank all those who have contributed data and advice throughout the study.



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Executive Summary

This study assesses the business case for utilizing purpose-grown biomass for heat and power generation in Ontario. The economics of growing major field crops in Ontario are reviewed to estimate the gross and net margins per acre. The cost of energy from purpose-grown biomass is compared with other energy sources available in Ontario. The production cost and acceptable margins of selected purpose-grown crops are estimated. The economics of biomass aggregation, which mainly includes the transportation and processing of biomass into pellets, are analysed. The generation of heat and power from purpose-grown biomass is considered for both centralized and distributed energy systems. The potential markets for purpose-grown biomass are identified, and supports required to develop the purpose-grown industry in Ontario are suggested. The conclusions and recommendations of the study are provided for Ontario Federation of Agriculture and other stakeholders.

There is a business case in favour of utilizing purpose-grown biomass for heat and power generation in selected markets in Ontario. Producers can cultivate purpose-grown biomass crops with a margin comparable to that of cash crops, while reaping the soil improvement and other environmental benefits of perennial grasses. The business case is expected to improve significantly with yield increases of purpose-grown crops by advances in genetics and agronomy. Since there is a future for the purpose-grown biomass industry, it is desirable to include these crops in Ontario's agricultural system. The improvements in grain prices in recent years have increased the opportunity cost of farm land in Ontario. Risk-sharing mechanisms, such as establishment loans and crop insurance programs, should be created to support the development of the purpose-grown biomass industry in order to compete successfully for crop land.

The acceptable price of purpose-grown biomass at farm gate in Ontario ranges from \$104.4/tonne to \$148.7/tonne, based upon industry-based inputs and average production and cost estimates. Of the purpose-grown crops identified, miscanthus offers the lowest production cost due to its comparatively high yield. Based on the analysis presented in this report, the acceptable price of miscanthus bales at farm gate is \$104.4/tonne, comparable with the margins of conventional cash crops. The establishment cost of miscanthus including the fixed costs is \$1179.3/acre, but can vary widely from farm to farm as producers are just learning how to grow the crop. A decrease in the establishment cost by \$300/acre will reduce the acceptable price of miscanthus bales at farm gate by approximately \$7/tonne. The acceptable price of switchgrass bales at farm gate is \$135.7/tonne. The acceptable price of biomass bales at farm gate for Tall Grass Prairie (TGP) and sorghum are \$148.7/tonne and \$103.9/tonne, respectively. Although TGP offers the maximum environmental benefits, information on fuel quality of the mixed biomass is limited, and the higher establishment cost and the relatively lower yield could be issues at present. The higher moisture content of current sorghum species at harvest is also an issue in using this feedstock for heat and power generation.

The development of a biomass aggregation chain in Ontario is required to establish a purpose-grown crops industry. There are a few biomass aggregators or pellet mills in Ontario. However, most of these are relatively small with a processing capacity of 1 – 4 tonne/hr. Other supply chain components of growing the crops and transportation of biomass are already established to a certain extent. The total cost of biomass processing, i.e., pelletizing, is estimated at \$38.88/tonne, which includes the sub-total processing cost of \$23/tonne and a financing cost of \$15.88/tonne. For this total processing cost, investing in a new agricultural pellet mill would provide a return on equity of 17.5%. A pellet mill with a capacity of 150,000 tonne/yr or 20 tonne/hr is considered the optimum size to draw purpose-grown biomass from a 100 km radius and was used for the processing cost estimations in this report. For the centralized heat and power generation system, which usually has a longer total transportation distance, the total cost of biomass transportation in Ontario is \$40-50/tonne. For the distributed heat and power generation system, which has relatively shorter total transportation distance, the total cost of biomass transportation in Ontario is approximately \$30/tonne. The total cost of miscanthus and switchgrass pellets to end users are \$172.45/tonne and \$203.75/tonne, respectively.

Space heating applications, using heating oil and propane are potentially profitable markets for purpose-grown biomass pellets in Ontario. Currently, the costs of heating oil and propane to end users are approximately $28.42/GJ and $30.58/GJ, respectively. Using our assumptions, miscanthus and switchgrass pellets would cost $9.32/GJ and $11.01/GJ, respectively, at consumer's gate. The fuel cost of such space heating applications could be reduced by approximately 65% by switching to purpose-grown biomass pellets. A distributed heat and power generation system, which generates biomass heat and power integrated with other agricultural activities, could be financially viable. The total capital cost of a distributed system, with an electricity generation capacity of 50 MW and heat generation of 50 MW, is estimated at $175 million. The system will consume about 300,000 tonne/yr of biomass. The return on equity for the distributed heat and power generation is 4 – 20%, depending on the cost of biomass and the price of heat.

Creation of markets, well-designed risk-sharing mechanisms, and investing in the development of high yielding crops are critical in establishing a purpose-grown biomass industry in Ontario. Purpose-grown crops will provide business diversification to Ontario's producers and offer many soil improvement and other environmental benefits. The biomass market in the space heating applications, where heating oil and propane are currently used, should be assessed in detail as an immediate potential. Well-designed risk-sharing mechanisms, such as establishment loans and crop insurance programs, should be created in consultation with farming community and other stakeholders. The agricultural organizations in Ontario should collaborate with the forestry sector to access the European biomass pellet market, which is rapidly expanding. The feasibility of developing a private-public funded demonstration plant, which generates biomass heat and power integrated with other agricultural activities, should be investigated. The long-term goal of the purpose-grown biomass industry in Ontario should be the development of local industries which manufacture diverse bio-products. The socio-economic benefits of the purpose-grown biomass industry should be quantified and communicated to policy makers.

Chapter 1 – Economics of Purpose-Grown Biomass

Growing biomass specifically for the generation of heat and power has attracted the interest of Ontario's agricultural community. Agricultural biomass can also be used to produce cellulosic bio-fuels, bio-chemicals and bio-composite materials. Purpose-grown crops such as miscanthus and switchgrass could provide a business diversification option for Ontario farmers. However, information on production costs and margins for these purpose-grown crops is very limited. This chapter investigates major cost items of selected purpose-grown crops and determines the acceptable pricing of biomass at farm gate. Net margins of purpose-grown crops are compared with traditional cash crops (hay, grain corn, soybeans and wheat). This section summarizes the economics of producing purpose-grown biomass in Ontario.

1.1 Major Crops in Ontario and Profit Margins

Ontario is blessed with productive farms, having approximately 50% of Canada's Class 1 agricultural land. Although farms in Ontario represent about 8% of the total agricultural land in Canada, the share of province's agricultural sector is 15-20% of the Canadian total farm receipts (Statistics Canada). Improvements in grain prices in recent years have increased the nominal income of farmers. However, the agricultural sector in Ontario is facing challenges such as higher input costs for farm operators, declining cattle industry, and unfavourable economies of scale due to relatively smaller farms. There are favourable economic conditions in Ontario through the Feed-in-Tariff program to convert biomass to energy to meet the high demand for electricity and heat energy needed by manufacturing and petro-chemical industries and by a large consuming population base. Diversifying the production of agricultural products to include purpose-grown biomass and linking with the existing strengths of Ontario is likely the logical strategy to pursue. Therefore, growing purpose-grown crops for generation of power and heat and for industrial applications should be investigated as a diversification option.

The major field crops in Ontario are hay, soybeans, grain corn, and winter wheat, collectively representing approximately 89% of total field crop area. The percentage contributions of these major field crops to the Ontario's total are shown in Figure 1.1, which is based on 2007-2011 five year average data compiled from Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Field Crop Statistics.

Hay is the largest crop in Ontario with 2.47 million acres, representing 29% of the total field crops. About 2.32 million acres is used to grow soybeans, the second largest crop in Ontario, which produces over 75% of Canadian supply. Grain corn is the third largest crop in Ontario with 1.86 million acres. Winter wheat, accounting for 11% of the total, is the fourth largest crop although acreage of this crop fluctuates from year to year more than that of other major crops. Other field crops, which include fodder corn, barley, spring wheat, mixed grain, beans, oats, rye, tobacco, and canola, occupy approximately 11% of total field crop area in Ontario. This study focuses only on the four major crops, namely hay, soybeans, grain corn, and winter wheat in order to understand the economics of farming operations in Ontario and to use the information as a baseline comparison to purpose-grown biomass.

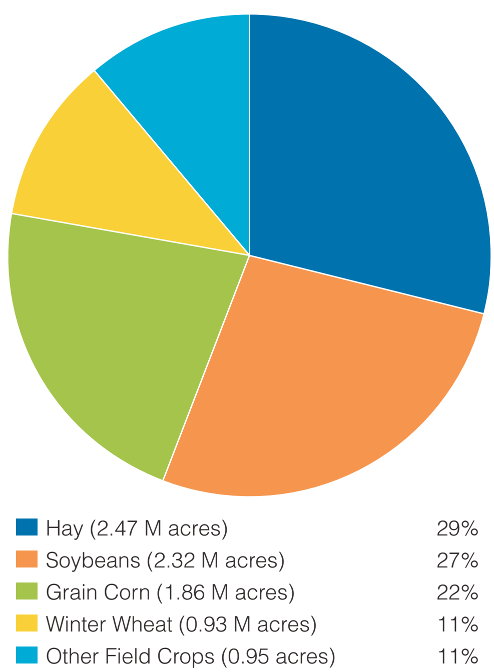

Figure 1.1 Acreages of Ontario's Major Field Crops in Percentage of Total (Source: 2007-2011 Average Data from OMAFRA Field Crop Statistics)

Readers are also reminded of the conversion of some pasture land to crops as the beef industry continues to adjust downwards.

Table 1.1 summarizes the economics of growing major field crops in Ontario. Yields and revenues, variable and fixed costs, and gross and net margins of the major crops are given in Table 1.1. Due to a wide range of soil quality in the province yield estimates used in the study are fairly conservative. This is also true for the price of grains, given the recent improvements in grain market prices. Data are based on OMAFRA crop budget worksheets and personal communications with a number of farm operators. Variable cost items include seed, fertilizers, chemicals, crop insurance, seeding, harvesting, storage and handling, fuel and lubricants, labour, equipment repair and maintenance, and interest on operating capital. Fixed cost items include depreciation of equipment, land cost, and interest on term loans. Gross margin is calculated by subtracting variable costs from the revenue. Net margin is the gross margin less the fixed costs.

As shown in Table 1.1, the cost of land is assumed at $100/acre for this study. Actual land cost in Ontario ranges from $50/acre to over $250/acre, depending on the quality of soil. Crop yields would also vary accordingly. For instance, the yield of grain corn could be greater than 180 bushels/acre for farms with the land cost of $250/acre. The grain corn yield of 150 bushels/acre can be expected for $100/acre land, as assumed in Table 1.1. Net margin, however, would remain relatively the same for all productive farms. If hay is grown as a cash crop, i.e. selling hay to others, net margin is close to zero. However, if hay crops are grown for the owner's cattle, net margin may come from the livestock operation. Based on the net margins of the major crops shown in Table 1.1, it can be assumed that

Table 1.1 Economics of Growing Major Field Crops in Ontario

	Hay	Soybeans	Grain Corn	Winter Wheat
Acreage in Ontario ('000 acre)	2,472	2,316	1,857	932
Yield and Revenue				
Yield (bushel/acre or tonne/acre)	3.5	42	150	76
Price ($/bushel or $/tonne)	110	12	5	5.4
Straw (tonne/acre)				0.75
Straw Price ($/tonne)				60
Total Revenue ($/acre)	385	504	750	455.4
Variable Cost Items				
Seed ($/acre)	60	56	91	49
Fertilizers and Chemicals ($/acre)	60	65	138	76
Other Operating Costs ($/acre)	141	113	236	111
Total Variable Costs ($/acre)	253	234	465	236
Fixed Cost Items				
Depreciation ($/acre)	19	25	28	30
Land Cost ($/acre)	100	100	100	100
Other Fixed Costs ($/acre)	16	21	24	28
Total Fixed Costs ($/acre)	135	146	152	158
Gross Margin (Rev. – Total Variable Costs) ($/acre)	132.3	270.0	285.0	219.4
Net Margin (Gross Margin – Total Fixed Costs) ($/acre)	-2.7	124.0	133.0	61.4

Note: Acreages of field crops are 2007-2011 five year average complied from OMAFRA Field Crop Statistics the average net margin of Ontario's farm growing field crops is about $100/acre at grain prices reported in recent years.

1.2 Purpose-Grown Crops for Energy Applications

Purpose-grown crops are plants cultivated to produce biomass which have non-traditional applications such as heat and power generation, bio-fuels, bio-chemicals and bio-composite materials. This study focuses on heat and power generation. Ideal attributes of purpose-grown biomass for heat and power generation include low cost, low crop maintenance, high yield, low moisture content, greater energy content, good fuel characteristics and minimal environmental risks. Purpose-grown crops could be categorized as either woody or herbaceous. Short rotation coppices such as willow and poplar are examples of woody crops. Herbaceous crops are mostly perennial crops and include miscanthus, switchgrass, Indian grass, reed canary grass, big blue stem, and native tall grasses. An exception is sorghum, which is an annual crop.

Personal communication with the farming community reveals that herbaceous crops are preferred to woody crops. Ontario's farmers have a great deal of experience with hay production, which is the largest field crop in the province, and most equipment used for haying can be employed to grow and harvest herbaceous crops with the exception of specialized planting equipment required for miscanthus and prairie grasses. Miscanthus and switchgrass are the most widely grown herbaceous crops in Ontario with several hundred acres at commercial and semi-commercial scales. Tall Grass Prairies (TGP) are also grown in Ontario for land restoration and other environmental benefits. Sorghum is currently grown as an annual forage crop in Ontario and is being considered as a potential crop for power and heat generation due to its high biomass yield. As producers develop strategies to provide year round supplies of fresh biomass to end users, the use of sorghum in a crop mix becomes more important. Since this study intends to gather relatively reliable field data on costs and yields, only purpose-grown crops at commercial or semi-commercial scales in Ontario are considered. Therefore, miscanthus, switchgrass, TGP and sorghum are examined to determine the economics of producing purpose-grown biomass.

1.2.1 Miscanthus

Miscanthus is currently the highest yielding purpose-grown crop producing biomass suitable for generation of power and heat through direct combustion. This herbaceous perennial grass possesses the efficient C4 photosynthetic pathway, and requires relatively low amount of nutrients and water. Once established miscanthus becomes perennial and can be productive with a stable yield for 10-15 years. Over 500 acres of miscanthus in Ontario have shown that a few varieties of this purpose-grown crop can be successfully grown in this climate and soil with reasonable yields of 7.5 tonne/acre.

Most miscanthus genotypes are sterile hybrids producing no viable seeds. Therefore, miscanthus is planted from either rhizomes or small plants called plugs. Miscanthus is usually planted in the spring at 6,000 rhizomes or plants/acre. Winter survival during the first year of establishment can be an issue for this crop in Ontario given the frequency of severe winters in some regions. Therefore, selection of an appropriate genotype or variety for a specific agricultural land is of critical importance for the successful establishment. Agricultural organizations such as the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and Ontario Soil and Crop Improvement Association (OSCIA) could provide advice to farmers on the selection of miscanthus varieties and crop establishment.

Although miscanthus grows fairly quickly, first-year growth is usually insufficient to be economically worth harvesting. The crop can be harvested from the second year onward. Miscanthus usually reaches a mature yield in the 4th year from establishment. After it is established, new shoots emerge in early spring and grow rapidly in summer to produce biomass. Miscanthus leaves fall off in the winter, providing nutrients for soil. Almost leafless miscanthus can be harvested in winter or early spring. Leaving miscanthus to overwinter in the field partially leaches out nutrients which are usually unwanted chemicals in the combustion process of biomass. Further pre-processing may be required to remove unwanted nutrients in order to meet end user fuel specifications.

Information gathered during this study indicates that the establishment cost of miscanthus varies from $800/acre to $2,000/acre, depending on the price of rhizomes or plugs, royalties, soil types and equipment used. Others have indicated lower costs of establishment (Dean Tiessen, personal communication). The current yields of miscanthus varieties planted in Ontario range from 6 tonne/acre to 12 tonne/acre at commercial and semi-commercial sites. An average yield of 7.5 tonne/acre is used for this analysis. The yield of miscanthus is more sensitive to the soil quality than other native tall grasses such as switchgrass and Indian grass.

1.2.2 Switchgrass

Switchgrass is a perennial warm season grass native to North America. Like miscanthus, switchgrass grows through the C4 photosynthetic pathway, offering low nutrient requirement and efficient water use. Since it is a native plant, switchgrass adapts to a wide range of soil and has a good resistance to drought, pests and diseases. Once it is established, switchgrass will remain productive for 15-20 years with a stable yield. There are over 500 acres of switchgrass in Ontario at commercial and semi-commercial scales, providing biomass to space heating, animal bedding, and bio-composite material markets.

The prominent advantage of switchgrass over miscanthus is that it can be easily established from seed, lowering the initial investment. Switchgrass can be seeded in the spring at a rate of 6 - 8 lbs/acre. Nott Farms in Clinton, Ontario successfully experimented with co-seeding of switchgrass and spring wheat during establishment. That strategy provided income from harvesting spring wheat in the summer during the first year of switchgrass establishment. There are a number of switchgrass varieties available for different climates and soil types, and extensive research and development in crop genetics is in progress. For the selection of the latest varieties, OMAFRA and OSCIA could provide helpful information.

No switchgrass harvest can be expected during the first year of establishment. A low yield of about 1 tonne/acre may be produced in the second year. Switchgrass reaches its mature yield by the third year, and economical annual harvests can take place starting from the third year. Cutting switchgrass in the fall and baling in early spring is the favoured harvesting option to leach out nutrients to soil in winter months. All farming operations for switchgrass can be done using existing equipment.

The establishment of switchgrass could cost $350 - $450/acre, depending on the seed source, soil types and labour costs in the specific region. The current yields of switchgrass varieties in Ontario range 3-6 tonne/acre at commercial and semi-commercial sites. Similar yields and establishment costs can be expected for other monoculture native tall grasses such as Indian grass, big blue stem, and Canadian rye.

1.2.3 Tall Grass Prairies

Tall grass prairies (TGP) consist of mixed native plants, both tall grasses and nitrogen-fixing small plants. Producers growing TGP in Ontario have done so as a means of addressing soil erosion issues, restoring native plants for ecological reasons and increasing biodiversity habitat. There are over 3,000 acres of TGP in Ontario, mainly on non-crop land. If a biomass market is created for TGP, the plantation could expand into some crop land.

Establishment of mixed prairie swards is more complex than establishing a monoculture crop and requires specialized planting equipment. There is no set definition for which species should be planted, and it is area-specific. There are over 40 species of native grasses and plants available for Ontario's land and typical establishment include up to 10 species in a plot. The Rural Lambton Stewardship Network (RLSN) is one of the organizations in Ontario with expertises in TGP and offer TGP establishment service.

Similar to miscanthus and switchgrass, TGP are perennial and no biomass harvest can be done in the first year of establishment. A small amount of biomass, possibly up to 1 tonne/acre, could be produced in the second year. The mature yield of TGP will be reached in the third year. Some TGP species can overwinter without decay. However, it is not certain that all TGP species could be left in the field in winter months without significant biomass losses. More field research is in need to determine the optimum harvesting schedule for TGP.

Since the selection of TGP species and seeding is a specialized service at present, the establishment of TGP could cost up to $2,000/acre, depending on the topography of the land and species selected. If TGP are grown on field crop land at a large scale, the establishment cost could decrease to < $1,000/acre. The yield of TGP ranges from 3 tonne/acre to 6 tonne/acre at current plantations in Ontario. There may be tradeoffs between biomass yields and ecological objectives.

1.2.4 Sorghum

Forage sorghum could be a potential purpose-grown crop for power and heat generation due to its high biomass yield. Sorghum is a warm-season, frost-sensitive annual crop. There are many types of sorghum including varieties suitable for biomass. As a tropical grass with the same C4 photosynthetic pathway as miscanthus, sorghum efficiently utilizes sunlight and soil moisture to quickly accumulate large amounts of biomass. Since sorghum is an annual crop, it provides the crop rotation flexibility to farm operators who want to participate in the spot biomass energy markets and provide flexibility to supplying biomass at different times of the year. Forage sorghum is not a very widely grown crop in Ontario, and it is estimated less than 2,000 acres are used to grow forage sorghum in this province.

Sorghum is planted from seeds after the threat of frost in the spring, which means delaying planting until the end of May or the first week of June to allow for high growth. Selection of appropriate Sorghum varieties, correct seeding rates and suitable agronomic practices for specific land are important to maximize yield. Advice and services can be obtained from OMAFRA or private firms like AERC Inc. in Simcoe or CERES in Pennsylvania to grow sorghum for energy applications.

Unlike miscanthus and switchgrass, sorghum can be harvested 2-3 times before the first frost comes for a maximum yield. The issue with sorghum for direct combustion energy applications is that its moisture content at harvest could be as high as 80%. Over-wintering current sorghum varieties for baling in the spring could lead to substantial biomass loss due to the rapid decay of wet biomass. Development of new sorghum varieties which can be overwintered is underway by a number of organizations. Commercialization of these new sorghum varieties is likely 3-5 years away.

Variable and fixed costs of growing annual sorghum crop are approximately $500/acre and $150/acre, respectively. The yield of sorghum at commercial sites in Ontario is 30-35 tonne/acre at 80% moisture content. This yield, if expressed in dry biomass, is comparable to that of miscanthus (10-15% moisture content). Pests and diseases can negatively affect the yield of sorghum. A great deal of current research and development work on sorghum for energy applications could result in this annual crop being a leading purpose-grown crop in a few years.

1.3 Cost of Biomass Production and Margin

Acceptable pricing of purpose-grown biomass at farm gate is dependent on total cost of production and net margin comparable to that of traditional cash crops. Current average farm size in Ontario is assumed to be 300 acres, and most farms are owned by the operators. The average net margin of $100/acre as discussed in Table 1.1 and the land cost of $100/acre would allow for a net income of $200/acre. Accordingly, an operator with the average farm size of 300 acres would generate a net income of $60,000/yr. Farmers with higher cost land will earn more due to higher yields. These parameters were included in the analysis.

The economics of growing miscanthus, switchgrass, TGP, and Sorghum are given in Table 1.2 – Table 1.5. As shown in these tables, the economics of growing purpose-grown crops considers yields, revenues, variable cost items and fixed cost items. OMAFRA crop budget worksheets for hay and switchgrass (see Appendix B) were used as a basis for perennial purpose-grown crops. Cost items were modified depending on the difference in amount and nature of work between hay crops and the specific purpose-grown crop. Consultation with Ontario's growers of purpose-grown crops was also the major information source for this study. Cost inflation of approximately 2% is factored in the economics spreadsheets. Acceptable price of biomass is calculated to obtain the average net margin of $100/acre.

Miscanthus represents the best case scenario for biomass production based on its yield. The acceptable price of miscanthus bales at farm gate is $104.4/tonne generating a net margin of $16/tonne for farm operators. As discussed before, the yield of current miscanthus varieties could be improved to more than 10 tonne/acre on very productive land with a corresponding greater than $250/acre land cost. However, the acceptable price of miscanthus would remain approximately the same, since fixed costs increase due to higher land cost. Total establishment cost of miscanthus is estimated at $1,179/acre which include all fixed cost items as shown in Table 1.2. Note that this is a current average value, and there is a significant range for the cost of establishment.

The establishment cost of switchgrass is relatively less compared to that of miscanthus since switchgrass is planted from seeds. A total of $425/acre, which includes the fixed cost items such as land cost, will be required to establish switchgrass. Based on the other cost items as shown in Table 1.3, the acceptable price of switchgrass bales at farm gate is $135.7/tonne, which provides $27.7/tonne of margin for farm operators. Similar to miscanthus, the yield of switchgrass could be as high as 6 tonne/acre on higher cost productive land. The acceptable price would again not change significantly due to higher land cost.

TGP is established from seeds like switchgrass; however, its establishment cost is higher than that of switchgrass due to specialized nature of planting and equipment. It would cost $910/acre, including fixed cost items, to establish TGP. As shown in Table 1.4, acceptable price of TGP bales at farm gate is $148.7/tonne, which would produce a margin of $29.8/tonne.

As given in Table 1.5, variable costs and fixed costs of the annual crop sorghum are $496.6/acre and $151/acre, respectively. The average yield of sorghum is estimated at 7.2 tonne/acre at 15% moisture content. The acceptable price of Sorghum bales at 15% moisture content at farm gate is $103.9/tonne. As mentioned before, the feasibility of utilizing sorghum for energy applications will be dependent on the commercialization of overwintering sorghum to reduce the water content of biomass.

Figure 1.2 summarizes the acceptable prices of selected purpose-grown biomass broken down into the

Table 1.2 Economics of Miscanthus

	Yr-1	Yr-2	Yr-3	Yr-4	Yr-5	Yr-6	Yr-7	Yr-8	Yr-9	Yr-10	Yr-11
Yield (tonne/acre)	0.0	3.0	6.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Price of biomass ($/tonne)	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4
Revenue ($/acre)	0	313.2	626.4	783	783	783	783	783	783	783	783
Net income from cover crop in Year-1 ($/acre)	95										
Variable cost items ($/acre)											
Propagation plugs	720.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilizer	40.0	80.0	45.0	45.9	46.8	47.8	48.7	49.7	50.7	51.7	52.7
Herbicides	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop insurance	15.0	15.3	15.6	15.9	16.2	16.6	16.9	17.2	17.6	17.9	18.3
Custom work (planting, applications, harvesting, bailing)	100.0	75.0	95.0	96.9	98.8	100.8	102.8	104.9	107.0	109.1	111.3
Fuel and lubricants	16.0	14.0	18.0	18.4	18.7	19.1	19.5	19.9	20.3	20.7	21.1
Equipment repair and maintenance	15.0	15.3	15.6	15.9	16.2	16.6	16.9	17.2	17.6	17.9	18.3
Labour	25.0	15.0	25.0	25.5	26.0	26.5	27.1	27.6	28.2	28.7	29.3
Interest on operating capital	48.3	48.3	48.3	48.3	48.3	48.3	48.3	48.3	48.3	48.3	48.3
Storage and handling	0.0	35.0	50.0	51.0	52.0	53.1	54.1	55.2	56.3	57.4	58.6
Other variable costs	4.0	5.0	7.0	7.1	7.3	7.4	7.6	7.7	7.9	8.0	8.2
Sub-total variable costs	1028.3	302.9	319.5	324.9	330.5	336.1	341.9	347.7	353.7	359.8	366.1
Fixed cost items ($/acre)											
Depreciation	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Land cost	100.0	102.0	104.0	106.1	108.2	110.4	112.6	114.9	117.2	119.5	121.9
Interest on term loan	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Other fixed costs	7.0	7.1	7.3	7.4	7.6	7.7	7.9	8.0	8.2	8.4	8.5
Sub-total fixed costs	151.0	153.1	155.3	157.5	159.8	162.1	164.5	166.9	169.4	171.9	174.4
Gross margin (Revenue - Variable costs) $/acre	-933.3	10.3	306.9	458.1	452.5	446.9	441.1	435.3	429.3	423.2	416.9
Net margin (Gross margin - Fixed costs) $/acre	-1,084.3	-142.8	151.6	300.5	292.7	284.8	276.6	268.4	259.9	251.3	242.5
Average gross margin ($/acre/yr)											262.5
Average net margin ($/tonne)											16.0
Average net margin ($/acre/yr)											100.1

production cost and margin in $/tonne at farm gate. The margin ranges from 13% to 20% of acceptable price for the selected crops. The higher the yield of a purpose-grown crop, the lower the percentage of margin in total acceptable price is. That is because the same net margin of $100/acre is assumed for all crops. The production costs in Figure 1.2 can also be considered as the break-even prices of growing these purpose-grown crops.

Sensitivity Analysis

The acceptable prices of selected purpose-grown biomass at farm gate calculated above are based on

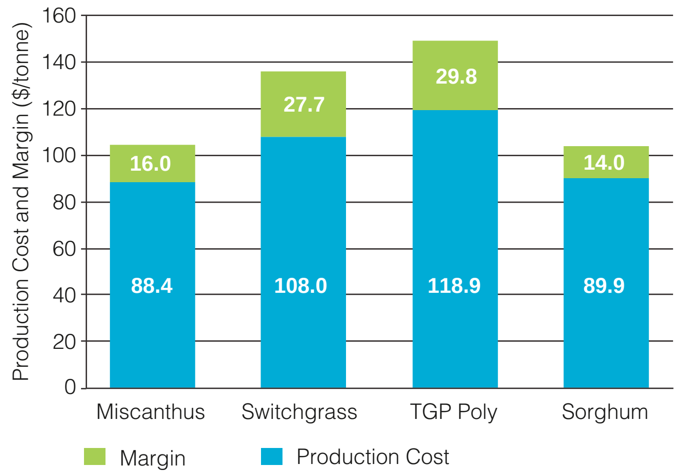

Figure 1.2 Production Cost and Margin of Selected Purpose-Grown Crops

Table 1.3 Economics of Switchgrass

	Yr-1	Yr-2	Yr-3	Yr-4	Yr-5	Yr-6	Yr-7	Yr-8	Yr-9	Yr-10	Yr-11
Yield (tonne/acre)	0.0	1.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Price of biomass ($/tonne)	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7
Revenue ($/acre)	0	135.7	583.51	583.51	583.51	583.51	583.51	583.51	583.51	583.51	583.51
Net income from cover crop in Year-1 ($/acre)	95										
Variable cost items ($/acre)											
Seed	135.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilizer	25.0	45.0	45.9	46.8	47.8	48.7	49.7	50.7	51.7	52.7	53.8
Herbicides	48.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop insurance	9.0	9.2	9.4	9.6	9.7	9.9	10.1	10.3	10.5	10.8	11.0
Custom work (seeding, applications, harvesting, bailing)	18.0	50.0	84.0	85.7	87.4	89.1	90.9	92.7	94.6	96.5	98.4
Fuel and lubricants	11.0	11.2	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4
Equipment repair and maintenance	12.0	12.2	12.5	12.7	13.0	13.2	13.5	13.8	14.1	14.3	14.6
Labour	13.0	13.3	15.0	15.3	15.6	15.9	16.2	16.6	16.9	17.2	17.6
Interest on operating capital	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Storage and handling	0.0	20.0	35.0	35.7	36.4	37.1	37.9	38.6	39.4	40.2	41.0
Other variable costs	3.0	4.0	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.9
Sub-total variable costs	286.5	189.4	233.2	237.6	242.1	246.7	251.4	256.2	261.1	266.1	271.1
Fixed cost items ($/acre)											
Depreciation	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Land cost	100.0	102.0	104.0	106.1	108.2	110.4	112.6	114.9	117.2	119.5	121.9
Interest on term loan	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Other fixed costs	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.9	6.0	6.1
Sub-total fixed costs	138.0	140.1	142.2	144.4	146.7	148.9	151.2	153.6	156.0	158.5	161.0
Gross margin (Revenue - Variable costs) $/acre	-191.5	-53.7	350.3	345.9	341.4	336.8	332.1	327.3	322.4	317.5	312.4
Net margin (Gross margin - Fixed costs) $/acre	-329.5	-193.8	208.0	201.4	194.7	187.8	180.8	173.7	166.4	159.0	151.4
Average gross margin ($/acre/yr)											249.2
Average net margin ($/tonne)											27.7
Average net margin ($/acre/yr)											100.0

(Note: Indian grass, big blue stem, Canadian rye and other monoculture tall grasses have similar establishment costs and yields) the best estimate of yields and cost items shown in Table 1.2 – Table 1.5. The sensitivity of the acceptable prices of biomass to selected parameters is analyzed in this section to understand the possible ranges of acceptable prices.

Figure 1.3 shows the effect of yields on acceptable prices of purpose-grown biomass with all cost items and net margins remaining the same. In this scenario, improvement in yields significantly reduces acceptable price of purpose-grown biomass. For instance, acceptable price of miscanthus could decrease from \$104.4/tonne to \$81/tonne if the yield of miscanthus on the same land is improved from 7.5 tonne/acre to 10 tonne/acre due to genetic advances or enhanced crop management.

The cost of land in Ontario ranges from \$25/acre to well over \$250/acre. The sensitivity of the acceptable prices of biomass to land cost is illustrated in Figure 1.4. The cost of land is the only parameter varied for the sensitivity analysis shown in Figure 1.4. If the yield of switchgrass, which is considered insensitive to soil, is maintained at 4.3 tonne/acre on \$50/acre land, the acceptable price of switchgrass will decrease to \$120.4/tonne.

Table 1.4 Economics of Tall Grass Prairies

	Yr-1	Yr-2	Yr-3	Yr-4	Yr-5	Yr-6	Yr-7	Yr-8	Yr-9	Yr-10	Yr-11	
Yield (tonne/acre)	0.0	1.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	
Price of biomass (\$/tonne)	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7	
Revenue (\$/acre)	0	148.7	594.8	594.8	594.8	594.8	594.8	594.8	594.8	594.8	594.8	
Net income from cover crop in Year-1 (\$/acre)	95											
Variable cost items (\$/acre)												
Seed	450.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Fertilizer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Herbicides	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Crop insurance	9.0	9.2	9.4	9.6	9.7	9.9	10.1	10.3	10.5	10.8	11.0	
Custom work (seeding, applications, harvesting, bailing)	200.0	50.0	84.0	85.7	87.4	89.1	90.9	92.7	94.6	96.5	98.4	
Fuel and lubricants	11.0	11.0	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	
Equipment repair and maintenance	12.0	12.2	12.5	12.7	13.0	13.2	13.5	13.8	14.1	14.3	14.6	
Labour	13.0	13.0	15.0	15.3	15.6	15.9	16.2	16.6	16.9	17.2	17.6	
Interest on operating capital	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	
Storage and handling	0.0	20.0	35.0	35.7	36.4	37.1	37.9	38.6	39.4	40.2	41.0	
Other variable costs	3.0	4.0	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.9	
Sub-total variable costs	775.9	149.3	204.7	208.2	211.8	215.4	219.1	222.9	226.8	230.7	234.7	
Fixed cost items (\$/acre)												
Depreciation	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	
Land cost	100.0	102.0	104.0	106.1	108.2	110.4	112.6	114.9	117.2	119.5	121.9	
Interest on term loan	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	
Other fixed costs	4.0	4.1	4.2	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	
Sub-total fixed costs	134.0	136.1	138.2	140.4	142.6	144.8	147.1	149.5	151.9	154.3	156.8	
Gross margin (Revenue - Variable costs) \$/acre	-680.9	-0.6	390.1	386.6	383.0	379.4	375.7	371.9	368.0	364.1	360.1	
Net margin (Gross margin - Fixed costs) \$/acre	-814.9	-136.7	251.9	246.2	240.4	234.5	228.5	222.4	216.2	209.8	203.3	
Average gross margin (\$/acre/yr)												245.2
Average net margin (\$/tonne)												29.8
Average net margin (\$/acre/yr)												100.2

(Note: Current establishment cost of TGP is relatively high at >\$1,500/ac, and is expected to decrease with economies of scale)

The cost item which varied the most during the information gathering of this study was the establishment cost of miscanthus. The sensitivity of the acceptable price of miscanthus bales at farm gate to the establishment cost is shown in Figure 1.5. Note that establishment cost of miscanthus includes the fixed cost items such as land cost, depreciation of equipment and interest on term loans. Every $300/acre decrease in the establishment cost would approximately reduce the acceptable price of biomass by about $7/tonne.

The yield of miscanthus is considered more sensitive to soil quality. Table 1.6 gives the land cost and yields scenarios for miscanthus and related acceptable prices of biomass at farm gate. The effect of the yield improvements on financial return of current miscanthus varieties on better land is offset by higher cost of land. As seen in Table 1.6, acceptable of price of miscanthus bales at farm gate remains relatively the same for the scenarios presented.

Table 1.5 Economics of Sorghum

	Annual
Yield (tonne/acre)	7.2
Price of biomass ($/tonne)	103.9
Revenue ($/acre)	748.08
Variable cost items ($/acre)	
Seed	150.0
Fertilizer	25.0
Herbicides	35.0
Crop insurance	15.0
Custom work (planting, applications, harvesting, bailing)	115.0
Fuel and lubricants	20.0
Equipment repair and maintenance	17.0
Labour	30.0
Interest on operating capital	12.6
Storage and handling	70.0
Other variable costs	7.0
Sub-total variable costs	496.6
Fixed cost items ($/acre)	
Depreciation	25.0
Land cost	100.0
Interest on term loan	19.0
Other fixed costs	7.0
Sub-total fixed costs	151.0
Gross margin (Revenue - Variable costs) $/acre	251.5
Net margin ($/tonne)	14.0
Net margin (Gross margin - Fixed costs) $/acre	100.5

(Note: Moisture content of ~ 80% at harvest is the issue; development of overwinter Sorghum is 3-5 years away)

Table 1.7 and Table 1.8 summarize the sensitivity analysis for miscanthus and switchgrass, respectively. It can be stated that the acceptable price of biomass at farm gate is significantly sensitive to the crop yield in percentage changes. The establishment costs of the crops selected in this study exhibit a considerable range; however, the effect of establishment cost on acceptable price of biomass is less pronounced compared to the yield. Although sensitivity of the

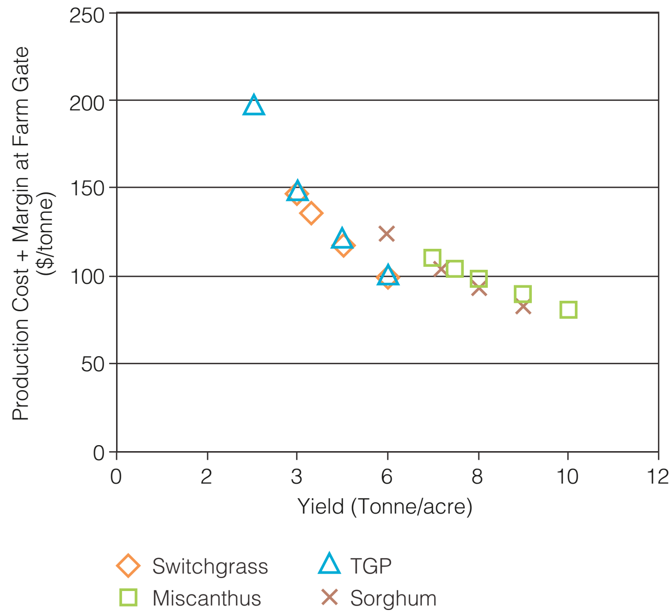

Figure 1.3 Sensitivity Analysis: Yield

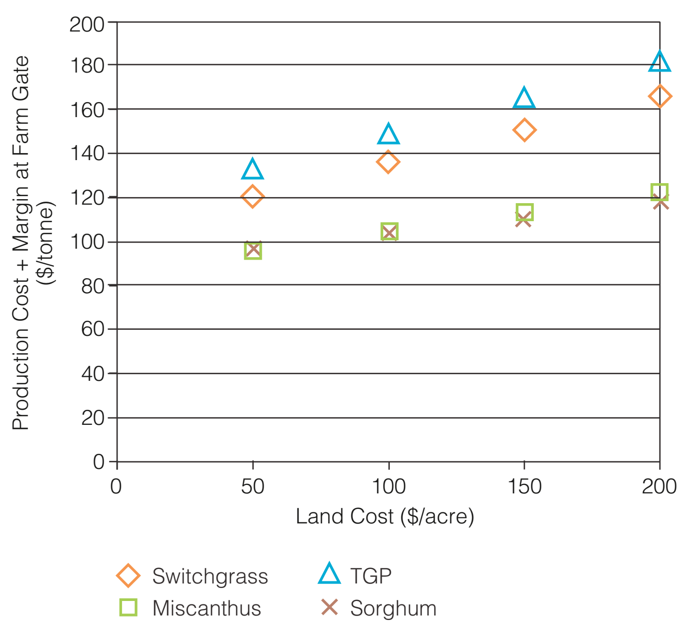

Figure 1.4 Sensitivity Analysis: Land Cost

acceptable price to land cost was conducted by keeping other parameters as constants, the reality is that higher the land cost the greater the crop yield.

As biomass production matures in the future, other factors may also influence the cost of production. For example, better planting equipment to achieve planting rates of 100 acres/day, emergence of specialized services for custom planting and harvesting and improved farm logistics with respect to on farm storage and movement of biomass will enable producers to lower production costs.

Producers are encouraged to look at their own costs of production (for example, different land costs, yield potential etc.) and use this model to evaluate their own circumstance. The data presented in this chapter represents one scenario of the costs of production based upon an assumed requirement for return on investment. These figures are subject to change based upon model inputs.

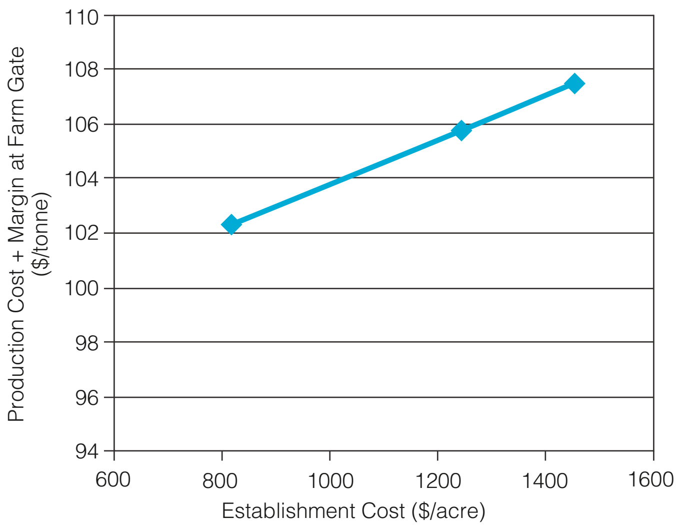

Figure 1.5 Sensitivity Analysis: Miscanthus Establishment Cost

Table 1.6 Land Cost and Yields Scenarios for Miscanthus in Ontario

Land Cost ($/acre)	Yield (tonne/acre)	Acceptable Price of Biomass at Farm Gate ($/tonne)
50	6.5	108.1
100	7.5	104.4
200	9.0	104.0
300	10.5	103.7
400	12.0	103.4

Table 1.7 Summary of Sensitivity Analysis for Miscanthus

	Base Case	Range	Change in Acceptable Price ($/tonne)
Yield (tonne/acre)	7.5	+ 1.5	- 15
		- 1.5	+15
Establishment Cost ($/acre)	1,179	+ 300	+ 7
		- 300	- 7
Land Cost ($/acre)	100	+ 100	+ 18
		- 50	- 9

Note: Base case acceptable price of miscanthus bales at farm gate is $104.4/tonne

Table 1.8 Summary of Sensitivity Analysis for Switchgrass

	Base Case	Range	Change in Acceptable Price ($/tonne)
Yield (tonne/acre)	4.3	+ 1	- 25
		+ 0.5	+18
Establishment Cost ($/acre)	425	+ 100	+ 5
		- 100	- 5
Land Cost ($/acre)	100	+ 100	+ 30
		- 50	- 15

Note: Base case acceptable price of switchgrass bales at farm gate is $135.7/tonne

Chapter 2 – Biomass Aggregation

In order to use purpose-grown biomass as feedstock for power and heat generation, biomass will be collected at farms and transported to biomass processing plants, usually pellets mills. To date, on-farm pelletization technologies have not been proven. Pellets have been selected as the best form of densified biomass to move through the transportation system (trucks, rail or ship) to end users due to their increase in density and ease of handling. Other products such as briquettes or whole bales for direct combustion are also possible for some markets. Accordingly, the analysis has been conducted on the basis of wood pellet production.

Biomass will go through a number of processes such as drying, chopping, possibly removing nutrients, grinding, possibly torrefying, and pelletizing. Biomass pellets will be then transported to the end-users by trucks, trains or ships. Biomass aggregation is analysed in this chapter to understand the economics of each component of the value chain. Estimates of the biomass pelletizing cost and total cost of biomass pellets to end-users are discussed.

2.1 Biomass Processing

2.1.1 Drying, Storage and Pelletization

Agricultural biomass collected for large-scale energy applications must be dried for year round storage to minimize dry matter loss and mould-related health risks. Biomass residuals should be densified to reduce the transportation cost. Studies report a wide range of storage costs for different types of biomass. Duffy and Nanhou (2002) reported $2.92/tonne storage cost for switchgrass, whereas Samson (2008) estimated a cost of $5/tonne for storing switchgrass at Nott Farms in Clinton, Ontario. Mani et al. (2006) estimated that the storage cost of wood pellets at the densification facility is $0.09/tonne. Material handling cost, which includes storage, was estimated by Uasuf and Becker (2001) at 6-9% of the total production cost of biomass pellets.

Biomass drying can represent a major cost associated with biomass densification, depending on the moisture content of the raw material. Mani et Al. (2006) estimated that the cost associated with drying wood residuals from 45% moisture at $10.30/tonne or about 30% of the total pelletizing cost. Energy for drying wood residuals represents 22% of the pellets' energy content and 70% of the total energy consumed in the pelletizing process (Karwandy, 2007). If harvested at an appropriate time, agricultural biomass from purpose-grown crops has relatively lower moisture content and therefore lower drying costs. Gildale Farms in Ontario currently pelletizes spring harvested agricultural biomass with no drying in the process.

For wood pellet mills, which process forestry biomass with over 40% moisture content, the capital cost of dryers can represent up to 45% of total capital investment (Mani et al., 2006; Karwandy, 2007; Murray, 2010a). Biomass is usually dried to 8 – 12% moisture content for the subsequent densification process. The moisture content of miscanthus or switchgrass can range from 10% to 15%. Total capital cost of pellet mills, therefore for purpose-grown biomass can be less than that of forestry biomass due to the lower moisture content of agricultural biomass and the related smaller requirement for dryers.

Grinding or milling is an operation within the biomass densification process chain. Biomass materials should be milled after drying to a size no larger than the anticipated final diameter of the pellets. Raw materials are usually sieved before grinding to remove foreign objects such as stone and metal. Mani et al. (2006) estimated a grinding cost of $0.95/tonne for wood residuals. Biomass from energy crops may have higher grinding costs due to additional sieving before grinding since agricultural biomass is more prone to contain foreign materials such as soil and stones compared to forest wood.

Pelletizing machines, also known as extruders, are available in a range of sizes. Generally, each increment of production of one tonne/hr requires 100 hp of energy input for forestry biomass. However, higher pellet outputs of 2 – 4 tonne/hr can be expected for agricultural biomass for the same 100 hp increment in energy input. Many pelletizing machines have a built-in steam conditioning chamber. Steam above 100 °C is used to soften biomass before it is densified. Steam conditioning is unnecessary but results in raw material that is less abrasive to pelletizing equipment. This helps reduce maintenance cost, but may increase the cost of operation due to the steam requirement. Biomass is forced through a die to develop cohesion in the pellet on the basis of dryness, compaction and form. There are two types of dies used in the pelletization process:

- Flat die: raw material is pressed though the top of a horizontally mounted die
- Rotary die: two or more rollers press raw material from inside a ring die to the outside where it is cut to desired length.

In both cases, a great deal of pressure is needed to force the raw material through holes in the die. Temperature of biomass increases with pressure and friction. Heat allows the lignin of the biomass to soften and the fibre to reshape into the pellet form. The wear and tear of the pelletizing equipment may be relatively higher for agricultural biomass than that of forest wood due to higher silica content.

2.1.2 Estimating Biomass Processing Cost

Samson (2008) estimated the total pelletizing cost of switchgrass including drying and grinding at $40/tonne for a 50,000 tonne/yr (6.7 tonne/hr) plant. Mani et al. (2006) suggested that there is a substantial gain in economy of scale up to a mill capacity of 75,000 tonne/yr (10 tonne/hr). The gain in the economies of scale beyond that capacity becomes marginal. The typical size of a wood pellet mill is 150,000 tonne/yr although the optimum size depends on the quantity of raw biomass materials available near the mill. RWE, a German electrical utility, recently constructed a wood pellet mill with a capacity of 750,000 tonne/y in Georgia, USA, to produce pellets for its European power plants (personal communication with utilities in Europe). Based on the operational data of the Wood Pellet Association of Canada, Murray (2010b) suggested the total production cost of wood pellets is $55/tonne, excluding the cost of raw biomass.

Based on information discussed with industry experts during this study, a financial model of biomass processing was developed and given in Table 2.1. Unit capital cost of agricultural biomass pellet mils are estimated at $100/tonne/yr. A pellet mill at a capacity of 150,000 tonne/yr (20 tonne/hr) would, therefore, cost $15 million to build. As shown in Table 2.1, the sub-total operation cost of the pellet mill is $23/tonne, and the sub-total financial cost is $15.88/tonne. Total cost of producing agricultural biomass is $38.88/tonne, excluding the cost of raw biomass. Note that this total processing cost would be higher for smaller pellet mills, such as 1 – 4 tonne/hr pellet mills currently available in Ontario.

2.1.3 Torrefaction of Biomass

Torrefaction is a fuel improvement process rapidly gaining interest from centralized coal-fired power plants considering co-firing or converting to 100% biomass fuel. This thermal pre-treatment drives off moisture and volatile organic materials and produces charcoal-like

Table 2.1 Estimation of Agricultural Biomass Processing Cost

General Parameters	Value
Unit capital cost ($/tonne/yr)	100
Pellet mill capacity (tonne/yr)	150,000
Debt to equity ratio	1.0
Interest rate (%)	6.0
Return on equity (%)	17.5
Loan repayment period (years)	10

Cost Items	Value
Operating costs	
Grinding ($/tonne)	2.00
Fuel for drying ($/tonne)	3.00
Utilities ($/tonne)	4.50
Labour ($/tonne)	6.00
Handling and storage ($/tonne)	2.50
Materials ($/tonne)	2.50
Repairs and maintenance ($/tonne)	2.50
Sub-total operating cost (M $/yr)	3.45
Sub-total operating cost ($/tonne)	23.00
Financing costs	
Total capital cost (M $)	15
Loan (M $)	7.50
Equity (M $)	7.50
Interest (M $/yr)	0.32
Loan repayment (M $/yr)	0.75
Return on equity (M $/yr)	1.31
Sub-total financing cost (M $/yr)	2.38
Sub-total financing cost ($/tonne)	15.88
Total	
Total processing cost ($/tonne)	38.88

solid biofuels that have greater hydrophobicity and may allow for uncovered storage similar to coal. The energy content per unit mass of torrefied biomass pellets is approximately 30% higher than that of raw biomass pellets, and energy content per unit volume of torrefied biomass pellets is about 90% higher than that of raw pellets (Kiel, 2007). This is slightly under the energy content of Pennsylvania coal (32 MJ/kg; http://www.energyjustice.net/coal/wastecoal/). The transportation cost of torrefied pellets is significantly reduced. Also, torrefied biomass likely has improved handling, milling and co-firing capabilities. Torrefaction technologies are currently entering the commercialization phase, and it is expected that torrefaction will soon contribute to large-scale heat and power generation from the biomass, depending upon the cost of production of torrefied material.

Estimating the cost of the torrefaction processes has limited accuracy since commercial units are rare and in their developmental infancy. Torrefaction costs are estimated based on the types of processing equipment, estimates of energy consumption, and the handling and preparation steps involved. Pricing of pilot torrefaction units from potential equipment manufacturers was also obtained during this study. Table 2.2 provides cost estimates for the torrefaction process, excluding pelletization. The cost of torrefying agricultural biomass is, therefore, approximately $12.5/tonne, which is an additional cost to the total processing cost in Table 2.1. This assumes that heat required in torrefaction is obtained from the combustion of volatiles recovered in the process. The torrefaction unit is considered to be an addition to the pellet mill.

2.2 Transportation of Biomass

Transportation cost for biomass is a function of distance, density of the biomass and mode of transportation.

Table 2.2 Estimation of Torrefaction Cost

Item	Value	Unit
Process capacity	150,000	tonne/yr
Capital cost	12	M$
Interest rate	6	%
Life of the system	10	yr
Amortized capital cost	1.63	M$/yr
Operating cost	0.24	M$/yr
Total cost/tonne	12.47	$/tonne

Note: Torrefaction system is considered as an addition to the pellet mill

Transportation usually represents a substantial portion of the total cost of the biomass fuel and can be the limiting factor for financial feasibility. For all modes (truck, rail and marine), biomass transportation cost has a fixed cost component and a variable cost component. Fixed cost includes loading and unloading, capital cost of rail cars, the marine port, etc based on covered horizontal storage. Variable cost component can be expressed in $/tonne/km, and includes fuel and operating costs. Figure 2.1 illustrates fixed cost and the variable cost of biomass transportation in general.

Biomass density has an important role in transportation cost estimates. For example, a standard wheat straw bale has a bulk density of about 120 kg/m3, and a truck with a volume of 100 m3 can transport bales weighing approximately 12 tonnes. However, biomass pellets with a bulk density of 580 kg/m3 or torrefied pellets with a bulk density of 800 kg/m3, would load the same truck with a 40 tonnes or more, limited only by the road load regulations. Obviously, it is more costly to transport bulky, less dense biomass than its densified counterpart. Constants used in the transportation cost models in this study are mentioned in Table 2.3 and are based on personal communications with industry personnel and a number of studies (Flynn, 2007; Samson, 2008; Sokhansanj and Fenton, 2006; Sorensen, 2005).

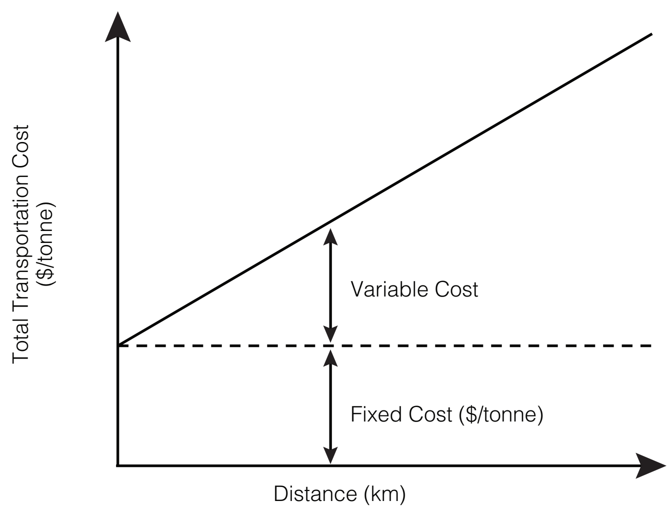

Figure 2.1 Fixed Costs and Variable Cost of Biomass Transportation

Transportation cost of biomass per dry matter tonne (DM t) for a given mode is calculated through:

$T_c = C_1 + C_2 L$

Where:
T_c = Transportation cost ($/DMt)
C_1 = Fixed cost constant ($/DM t)
C_2 = Variable cost constant ($/DM t/km)
L = Distance (km)

Purpose-grown biomass will likely be trucked from farms to a central biomass fuel processing facility, i.e., a pellet mill. Biomass pellets will then be transported to end-users by truck, train, and/or ship. Total transportation distance of agricultural biomass for power and heat generation will depend on how close the pellet mill is located to the source of biomass and the distance between the pellet mill and the end-user. Total transportation distance assumed in this study and the transportation scenarios are given in Table 2.4 with the estimates of the transportation costs for the scenarios considered.

Table 2.3 Transportation Model Constants for Different Modes for Biomass

Mode	C1	C2
Truck	6.84	0.1641
Rail	20.52	0.0333
Marine	23.52	0.0136

(Adapted from: Flynn, 2007; Samson, 2008; Sokhansanj and Fenton, 2006; Sorensen, 2005)

Table 2.4 Estimate of Transportation Distances and Costs for Purpose-Grown Biomass

General Parameters	Value
Density of raw biomass (kg/m3)	120
Moisture content of raw biomass (%)	15
Density of pellets (kg/m3)	580
Moisture content of pellets (%)	5
Average distance - farm to pellet mill (km)	50
Average distance - pellet mill to train station/marine port (km)	50
Average distance - train station/marine port to destination (km)	150
Transportation Costs	**Value**
Farm to pellet mill by truck ($/tonne)	17.30
Pellet mill to train station/marine port by truck ($/tonne)	6.32
Train station to final destination by train ($/tonne)	5.54
Marine port to final destination by ship ($/tonne)	5.55
Total transportation cost (truck+truck)	30.51
Total transportation cost (truck+truck+train)	29.16
Total transportation cost (truck+truck+ship)	29.17

Figure 2.2 provides the breakdown of total transportation costs into segments for each scenario. The first scenario "Truck+Truck" includes the trucking of raw biomass bales from farm gate to pellet mill and trucking of biomass pellets from the pellet mill to final destination. The average distance between farm and pellet mill is assumed at 50 km, and that between pellet mill and final destination is estimated at 150 km. These distances are based on the distribution of farm land in most agricultural regions of Ontario. Total cost of transporting purpose-grown biomass for "Truck+Truck" scenario is $30.51/tonne. Transportation distances and modes involved in other scenarios "Truck+Truck+Train" and "Truck+Truck+Marine" are shown in Figure 2.2.

As seen in Figure 2.2, the cost saving for using trains and ships in transporting biomass are not significant due to relatively short total transportation distances. Figure 2.3 gives the total transportation costs of the scenarios for longer distances. These longer transportation distances in Figure 2.3 could apply in the case of a centralized end-user like OPG Nanticoke Generating Station, for example, drawing biomass from across Ontario. Distances are estimated based on the relative location of OPG Nanticoke station and the acreages in most agricultural regions in Ontario. Cost savings of transporting biomass by trains or ships for these longer distances are more pronounced. Therefore, if purpose-grown biomass crops are to be used for

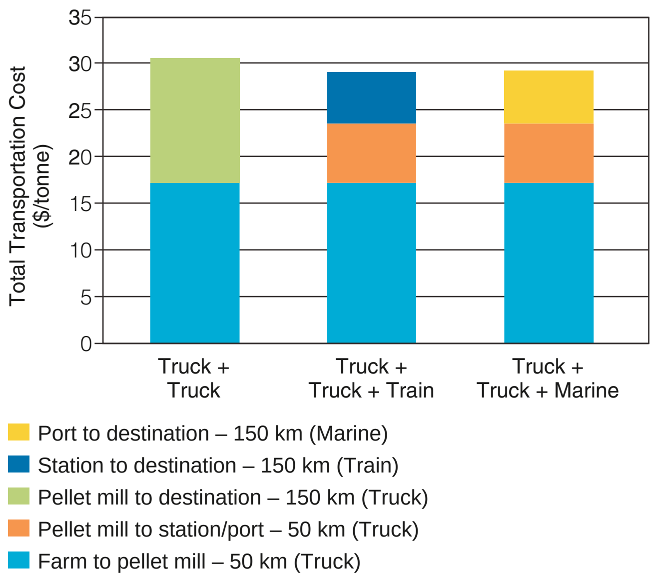

Figure 2.2 Breakdown of Total Transportation Cost for Purpose-Grown Biomass

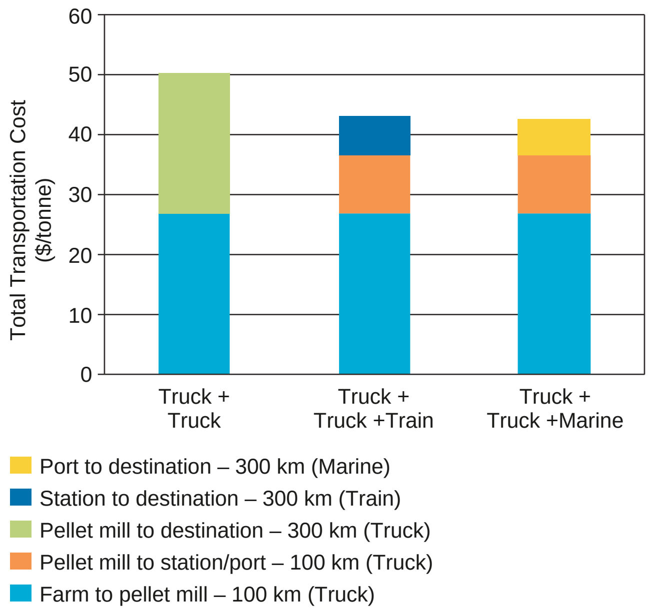

Figure 2.3 Breakdown of Total Transportation Cost for Longer Distances

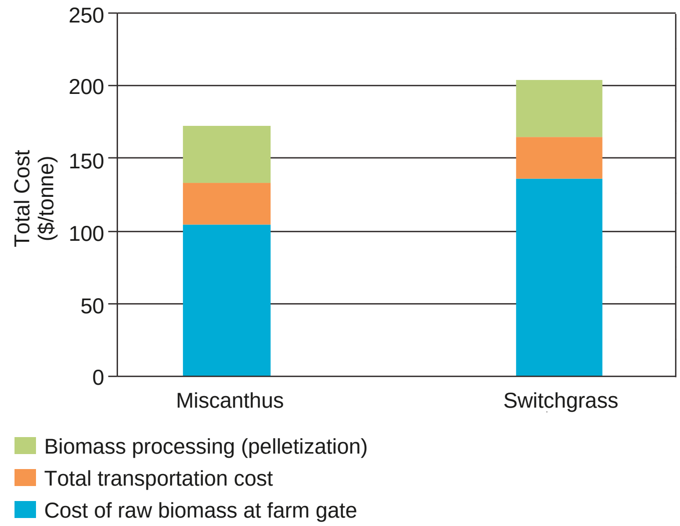

Figure 2.4 Total Costs of Miscanthus and Switchgrass Pellets to End Users

distributed power and heat generation, trucking is the likely mode of transportation. For a centralized power and heat generation or export markets, train and marine transportation modes could reduce total transportation costs.

2.3 Total Cost of Biomass to End Users

Total cost of purpose-grown biomass pellets to end users would be the sum of an acceptable price of biomass at farm gate, total transportation cost and biomass processing cost. Figure 2.4 provides the total cost of biomass for miscanthus and switchgrass pellets to end users. As indicated earlier, the acceptable prices of miscanthus and switchgrass bales at farm gate are $104.4/tonne and $135.7/tonne, respectively. Total average transportation cost of approximately $29.17/tonne and biomass processing cost of $38.88/tonne are added to the cost of raw biomass to estimate total cost to end users. Total costs of miscanthus and switchgrass pellets to end users, therefore, are $172.45/tonne and $203.75/tonne, respectively.

The cost of raw biomass, as seen in Figure 2.4, represents 61-67% of the total cost of biomass pellets for purpose-grown crops. The cost of raw biomass is usually less than 25% of the total cost in the case of forestry biomass pellets (Murray, 2010b). Information gathered during this study suggests that total cost of forestry biomass pellets for large-scale end users could be approximately $175/tonne. Wood pellets from British Columbia are currently being delivered at Europeans ports for $150-180/tonne (personal communication with industry experts). However, the expected increase in European demand for wood pellets in the next a few years could raise the price of wood biomass significantly.

Biomass from purpose-grown crops can be used as renewable feedstock to generate heat and power. In addition to lowering the emissions of greenhouse gases, purpose-grown biomass has a number of advantages over conventional and other renewable energy sources. However, purpose-grown biomass has to compete economically with other energy sources. The economics of generating power and heat from biomass at a centralized plant could be different f than that from distributed systems. Purpose-grown biomass has applications other than energy generation and also has competition from other biomass such as wood and agricultural residues. There are a few jurisdictions where the development of purpose-grown biomass is supported by government subsidies and grants.

3.1 Competing Renewable and Conventional Energy Sources

As presented in Chapter 2, miscanthus and switchgrass pellets could cost end users $172.45/tonne ($9.32/GJ) and $203.75/tonne ($11.01/GJ), respectively.. Figure 3.1 compares purpose-grown biomass pellets with other energy sources available in Ontario in $/GJ. The estimates of wood and fossil fuel energy prices in Figure 3.1 are based on data provided by the Kent Group (www.kentmarketingservices.com), the National Energy Board (www.neb.gc.ca), the Ontario Energy Board (www.ontarioenergyboard.ca), and information gathered from industry during this study. These energy costs are recent 6 month averages for the end users. A +/- 10% variation could be expected for specific cases.

The purpose of the comparisons in Figure 3.1 is to illustrate the order of magnitude differences in costs of energy sources in Ontario and to highlight the potential markets for purpose-grown biomass pellets. As seen in Figure 3.1, coal and natural gas are the most cost-competitive fuels in Ontario. Purpose-grown biomass pellets will not likely have any direct economic advantages in the areas where coal and natural gas can be accessed and used legally. Space heating applications, where heating oil and propane are heavily used, could provide potential markets for purpose-grown biomass pellets. The map of major natural gas pipelines are given in Appendix C to illustrate rural areas away from the natural gas pipelines where such potential markets exist. The fuel cost of such space heating applications could be reduced by approximately 65% by switching to biomass pellets. Purpose-grown biomass, however, will face significant competition from wood pellets in the space heating applications. Purpose-grown biomass does offer indirect economic benefits, however, in terms of infrastructure, jobs and small urban and rural stability.

Figure 3.2 compares average energy cost for electricity with electricity cost from selected renewable sources without delivery charges and taxes. An average Ontario electricity cost of $0.075/kWh is assumed, while the costs of electricity from renewable sources are based on published Feed-In-Tariff (FIT) rates. The average cost of electricity in Ontario is approximately $20.83/GJ. If all delivery charges are included, this average cost of electricity would be $30.56/GJ - $38.89/GJ, i.e., $0.11/kWh to $0.14/kWh. The cost of electricity from biomass is lower than that of wind and solar electricity, and biomass could provide renewable and dispatchable electricity on demand.

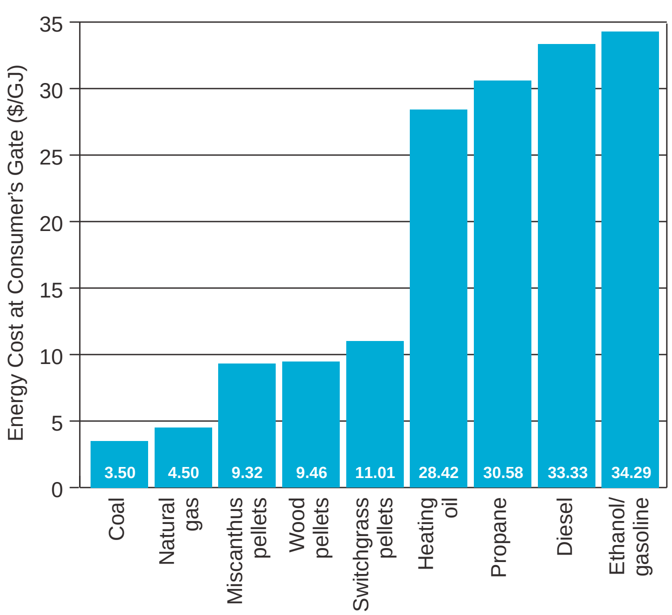

Figure 3.1 Comparisons of the Cost to the Consumer for Purpose-Grown Biomass Pellets and Other Energy Sources in Ontario

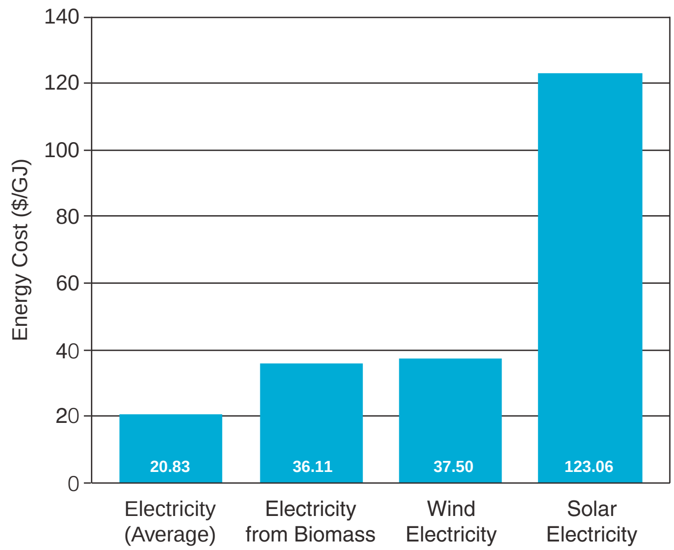

Figure 3.2 Comparisons of Average Electricity and Selected Renewable Electricity Costs in Ontario

3.2 Centralized vs. Distributed Energy Generation

Purpose-grown crops have received attention from Ontario's farming community, the Province of Ontario and Ontario Power Generation (OPG) as a potential alternative fuel for OPG in eliminating coal from the fuel mix for electricity generation. Estimating all cost items at a centralized electricity generating station is beyond the scope of this study. However, the cost of fuel is estimated for generating 1 TWh of electricity at a centralized electricity generating station for a few fuel sources, and the revenue from the sale of electricity is calculated in Table 3.1. The fuel-to-electricity conversion efficiency of 30% is assumed.

The electricity generating stations are paid approximately $0.10/kWh (http://ieso.ca) during peak hours. For this case, the fuel cost of coal would be 42% of the revenue. If a centralized generating station has access to natural gas at $4.5/GJ, the fuel cost would be 54% of the revenue. If the current FIT rate is applicable for using biomass as feedstock, the revenue for generating 1 TWh of electricity would be $130 million. The fuel cost of miscanthus pellets would be 86% of that revenue. Therefore, generating electricity only from purpose-grown biomass may not be financially viable unless the electricity from biomass is priced higher in the FIT rate or the price for biomass decreases.

Table 3.1 Revenue and Fuel Cost for Generating 1 TWh of Electricity at a Centralized Station

Price of Electricity	Revenue (M $)	Fuel Cost (M $)			
		Miscanthus ($173/tonne)	Switchgrass ($204/tonne)	Coal ($3.5/GJ)	Natural Gas ($4.5/GJ)
$0.10/kWh	100	112	132	42	54
$0.13/kWh	130				
$0.17/kWh	170				
$0.25/kWh	250				

Notes: 30% power generation efficiency

Most biomass energy generation systems in Europe are decentralized, and combined heat and power is usually the mode of operation. Decentralized energy generation may be viable at a few locations in Ontario; however, finding the matching heat and power demands may not be as easy as that in Europe due to different geographical distribution of industrial and the residential sectors. The total cost of purpose-grown biomass fuel would be reduced since pelletization may not be required, and total transportation cost could be lower due to the shorter distance between biomass source and end user. In addition to these benefits, jobs will be created in rural area.

The financial viability of a decentralized heat and power generation system is evaluated below. The assumptions and estimates are based on the experience of a biomass combined heat and power generation system in Europe, personal communication with industry experts, and the information available for a biomass combined heat and power generation plant to be built in Texas. The energy generation capacity of the system is assumed at 50 MW of electricity and 50 MW of heat. The estimated financials of the system are given in Table 3.2.

The unit capacity cost of biomass combined heat and power system considered is estimated $3.5 million per kW installed capacity of electricity generation. Total capital cost of the system is, therefore, $175 million. Other input parameters are given in the "General Parameters" section of Table 3.2. Given the low price of natural gas in Ontario, heat sale at $4/GJ is assumed for 4 months in a year. The revenue from heat sale is $2.1 million/yr, representing only 3.8% of the total revenue. The biomass combined heat and power system would generate electricity as a base-load plant and expect to receive the FIT rate of $0.13/kWh. As shown in Table 3.2, the Return on Equity (ROE) of the distributed energy generation system would be approximately 4.1%, which might be considered too low to attract investment. However, the expected changes in FIT rate for electricity from biomass could improve the ROE.

The ROE of the contemplated distributed energy generation would improve greatly if there is a heat demand through the year. There is a possibility that a mix of purpose-grown biomass and agricultural residues, such as corn stover and cereal straw, could be the feedstock. That would lower the cost of biomass fuel since such residues are expected to be less expensive. For instance, the price of wheat straw in southern Ontario ranges $50 - 90/tonne at farm gate, depending on logistic issues. As discussed earlier, propane and heating oil are used for space heating in some areas in Ontario. If distributed energy generation is installed in such areas, heat could be sold at a higher price. Table 3.3 gives the sensitivity analysis of ROE to the cost of biomass and the price of heat.

Table 3.2 Financial Analysis of Distributed Biomass Heat and Power Generation

General Parameters	Value
Capacity of the system (MWe)	50
Unit capacity cost (M$/MWe)	3.5
Debt to equity ratio	1.0
Interest rate (%)	5.0
Loan repayment period	15
Price of electricity ($/kWh)	0.13
Price of heat ($/GJ)	4.0
Cost of biomass bales ($/tonne)	120

Energy Generation and Revenue	Value
Electricity generation (MWh/yr)	408,000
Heat generation for sale (GJ/yr)	518,400
Sale of electricity (M $/yr)	53.0
Sale of heat (M $/yr)	2.1
Total revenue (M$/yr)	55.1

Cost Items	Value
Operating costs	
Biomass fuel (tonne/yr)	300,737
Biomass fuel cost (M$/yr)	36.1
Labour (M $/yr)	3.8
Repairs and maintenance (M $/yr)	1.2
Handling and storage (M $/yr)	0.7
Sub-total operating costs (M $/yr)	41.7
Financing costs	
Total capital cost (M $)	175.0
Loan (M $)	87.5
Equity (M $)	87.5
Interest (M $/yr)	3.1
Loan repayment (M $/yr)	5.8
Sub-total financing costs (M $/yr)	8.9

Net income (M $/yr)	4.4
Income tax (M $/yr)	0.9
Return on equity (%)	4.1

Note: Heat sale is assumed for only 4 months in a year

If the cost of biomass is reduced to $90/tonne, which could be possible with the inclusion of some agricultural residues in feedstock, the financial viability of the distributed energy generation system will be comparable to other renewable electricity projects. Further improvement in ROE is possible with greater heat demand, i.e., heat sale through the year. Therefore, distributed heat and power generation systems could be financially viable in Ontario; however, a careful selection of the site and finding the matching heat demand are of paramount importance.

Based on the peak heat demand of 1 MW/acre of a vegetable greenhouse in Ontario, the 50 MW of heat generated by the contributed energy generation system could provide heat to approximately 50 acres of greenhouses. This heat demand option would promote more agricultural activities in an area where the distributed energy generation is built. There has been growing interest in the development of community power in Ontario, and private/public financing of distributed energy generation systems is possible.

3.3 Alternative Markets of Purpose-Grown Biomass

As discussed in previous sections, selected space heating applications and distributed heat and power generation are potential markets in Ontario for purpose-grown biomass. European biomass demand for heat and power generation could also represent an opportunity for Ontario's agricultural biomass. Climate change policy has been the major driver in increasing European demand for biomass energy. Figure 3.3

Table 3.3 Sensitivity of the ROE of a Distributed Heat and Power Generation System

Cost of Biomass Bale ($/tonne)	Price of Heat ($/GJ)	Return on Equity (%)
90	4	12.3
	10	15.5
	20	19.9
120	4	4.1
	10	6.9
	20	11.6

presents the projection of biomass pellet demand from Europe by a number of companies and organizations.

The current demand for 10 million tonne/yr of biomass pellets in Europe could increase to as high as 85 million tonnes/yr but is more likely to be 30 – 50 million tonnes/yr in 5 years as shown in Figure 3.3. The majority of biomass fuel consumed in Europe at present is wood pellets. British Columbia has been a prominent supplier of wood pellets for Europe. However, wood pellets markets seem to be depressed in comparison with the demand prior to pre-global financial crisis. Industry sources suggest that wood pellets are currently delivered at $150 – 180/tonne at European ports, down from a high of $220-240/tonne in 2007-2008 (personal communication with industry experts).

The expected rapid increase in demand could improve the price of biomass pellets and create an export market for Ontario's purpose-grown biomass. Information gathered during this study suggests that there have been visits by European biomass end-users to Ontario for acquisition of forestry and agricultural biomass pellets. Collaboration with Ontario's forestry industry to access the European biomass market could provide a short to medium term business diversification for purpose-grown biomass. It should also be noted that agricultural biomass usually has fuel quality issues in comparison with forestry biomass due to higher

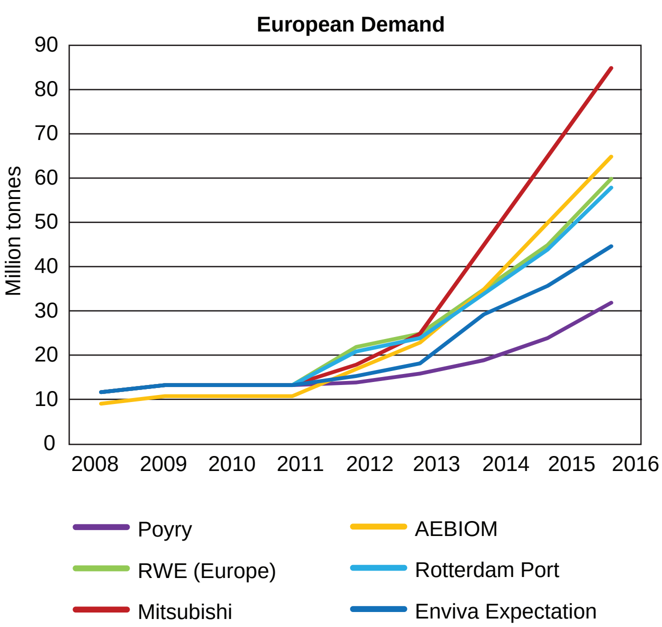

Figure 3.3 Projections of European Demand for Biomass Pellets by Different Companies/ Organizations (Source: Hirschler Fleischer)

concentrations of nutrients such as potassium and chlorine. Agricultural biomass usually has a higher ash content and lower ash melting temperature than wood. More research and development work is needed to improve the agricultural biomass for existing large-scale biomass energy electricity generators.

There are other agricultural biomass demands in Ontario such as livestock bedding, mushroom, strawberry and ginseng growing. These markets are mostly met by cereal straw available in the province. A new and developing speciality demand for agricultural biomass has been the bio-composite materials sector. Nott Farms in Ontario has been a major supplier of switchgrass for such a market. The bio-composite material market currently offers attractive prices for purpose-grown biomass; however, the present market size is relatively small. The development of a bio-composite material industry could be beneficial in creating an immediate alternative market for purpose-grown biomass. Cellulosic biofuel and biochemical production could become a market for purpose-grown biomass in a long term since intensive research and development efforts are underway.

3.4 Support for Development of Biomass Energy

Purpose-grown biomass could be included in the energy mix of Ontario for heat and power from purposes, more specifically in rural areas. The major advantages of purpose-grown biomass over conventional fossil fuels include:

- Renewable fuel source
- Less emission of greenhouse gases and negative carbon lifecycle balance (net carbon sequestration)
- Greater contribution to the rural economy

Development of renewable electricity generation is supported by FIT rates in Ontario. However, wind and solar dominate the renewable electricity offering in Ontario to date. Most of the bio-electricity developments in Ontario are through generation of electricity powered by internal combustion engines using biogas from cattle manure or municipal waste. The major advantages of energy from purpose-grown biomass over other renewable energy include:

- Carbon sequestration by first growing biomass above ground and underground

- Soil improvement by the massive root systems of perennial crops
- Lower cost (in comparison with solar and wind)
- Dispatchable (no negative electricity price issue)
- Greater potential to integrate with industries which have heat demand
- Foundation for bio-refineries in creating new bio-economy sector
- Job creation during the construction and the operation of the bio-energy facilities

Among the advantages mentioned, the ability of perennial purpose-grown crops to improve soil quality and prevent erosion should be noted. Ontario's farmers grow hay crops, which are also perennial, not only as feed for their cattle but also as a beneficial crop rotation to improve soil quality and to reduce pests and diseases. Since the cattle industry in Ontario has been declining, farm operators in some areas of Ontario no longer have the opportunity to include hay crops in their rotations. Furthermore, pastureland has become available to grow crops. Therefore, the development of purpose-grown biomass industry can fill the gap and increase the productivity of the agricultural sector in Ontario. Farm operators could ideally grow purpose-grown crops at a margin comparable to that of cash crops, while reaping the soil improvement and other environmental benefits of perennial grasses. The perennial purpose-grown crops should be a part of Ontario's integrated and improved agricultural system.

The development of energy generation from biomass is encouraged in many other countries by use of subsidies, grants, and other supports. The degree and type of supports vary from country to country based on the specific socio-economic conditions. These supports can be, in general, categorized as follows:

1. Biomass production and supply chains
   - Examples: Energy crop scheme in UK, Matching payment in US (BCAP)
   - 2012 US Farm Bill may impact on future program availability
2. Uptake and new installations
3. Biomass use, heat and power generation
4. Applied research, development and technology transfer
5. Advice, consultancy and other support

The first two categories are very limited, almost nonexistent, in Ontario. However, there are a number of programs available from Agriculture and Agri-Food Canada (AAFC) such as the Advance Payments program, AgriInsurance (crop insurance), Canadian Agricultural Loans Act, AgrInvest, and AgriStability which could be applicable to purpose-grown crops. . More information can be obtained at AAFC web site www4.agr.gc.ca/AAFC-AAC/.

The FIT rate for electricity from biomass would be part of the third category. The support from organizations like OMAFRA, OFA, OSCIA, Ontario Agri-Food Technologies, Erie Innovation and Commercialization, Ontario Fruit and Vegetable Growers' Association, Bioindustrial Innovation Centre, Sustainable Chemistry Alliance, and other commercialization programs could be considered as examples for the fourth and fifth categories.

The potential negative side effects of support to develop energy generation from biomass should be considered with great care. For instance, the US federal government provides up to $45/tonne in matching payments to businesses that collect, harvest, store and transport biomass waste to an authorized energy facility. That means sawdust or wood shavings may be twice as valuable if a lumber mill sells them to a biomass energy company instead of to a traditional buyer. This ancillary effect is negative for the composite panel industry which outranks the U.S. biomass energy industry in terms of employees and economic impact.

At current yields, purpose-grown biomass faces tough competition from forestry biomass for heat and power applications. If the development of purpose-grown biomass industry is to be considered as beneficial and a priority for Ontario's agricultural sector over the long term, support should specifically target the agricultural biomass. Continued support for the development of high yielding purpose-grown biomass cultivars should occur as yield is a primary determinant of profitability. Support such as a FIT rate and tax credits for installation of new biomass heating systems could be applicable to both agricultural and forestry biomass. However, support such as crop establishment loans, crop insurance and risk-sharing with the aggregators of agricultural biomass would specifically target the emerging purpose-grown biomass industry and place purpose-grown acreage on an equal plying field with other cash crops produced.

Chapter 4 – Summary, Conclusions and Recommendations

This study has assessed the business case of utilizing purpose-grown biomass for heat and power generation in Ontario. The scope of the study was outlined by Ontario Federation of Agriculture (see Appendix A). The economics of growing major field crops in Ontario was reviewed in terms of estimating the gross and net margins per acre. Selected purpose-grown crops which are proven to be successfully grown in Ontario and suitable for heat and power generation were examined. The production cost and acceptable margins of selected purpose-grown crops were estimated.

The economics of biomass aggregation, which mainly includes costs for transportation and processing of biomass into pellets, were analysed. Total cost of purpose-grown biomass for end-users was estimated. The generation of heat and power from purpose-grown biomass was considered for both centralized and distributed energy systems. The cost of energy from purpose-grown biomass was compared with other energy sources available in Ontario. The potential markets for purpose-grown biomass were identified, and supports required to develop the purpose-grown industry in Ontario were suggested. The conclusions and recommendations of the study are given in this section.

4.1 Summary of Findings and Conclusions

4.1.1 Biomass Production

Four field crops, namely hay, soybeans, grain corn and winter wheat, dominate Ontario's crops and collectively represent about 89% of total field crops in the province. The average net margin of soybeans, grain corn and winter wheat are approximately $100/acre in Ontario. If a farm operator is growing hay crops to sell, the net margin will be close to zero. However, if the hay crops are grown to feed on-farm cattle, the net margin is expected to come from the livestock operation. The required net margin is, therefore, estimated at $100/acre based on the average farm size and the current economics of major field crops in Ontario.

The establishment costs and yields of selected purpose-grown crops are estimated based on the information gathered from a number of sources, including OMAFRA crop budget sheets, OSCIA, literature and growers in Ontario. Since there are few established purpose-grown crops in Ontario, the data for establishment costs and yields exhibit a considerable range. For instance, the establishment cost of miscanthus ranges from $800/acre to $2,000/acre, excluding the fixed costs. Therefore, the best estimates of the cost items are considered for each purpose-grown crop, and a sensitivity analysis is performed to understand the impact on the production cost.

A financial spreadsheet model was developed to estimate the acceptable price of purpose-grown crops at farm gate. After the establishment year, a total of 10 years of production is considered for perennial crops. Increase in production costs due to inflation is also taken into account. Miscanthus offers the lowest production cost due to its high yield. The determined acceptable price of miscanthus bales at farm gate is $104.4/tonne to be comparable with the margins of conventional cash crops. The establishment cost is $1179.3/acre, including the fixed costs. A decrease in the establishment cost by $300/acre will reduce the acceptable price of miscanthus bales at farm gate by approximately $7/tonne. The mature yield of miscanthus on $100/acre land is estimated at 7.5 tonne/acre. Higher yields of up to 12 tonnes/acre can be expected on farms with higher land value. The sensitivity analysis suggests that the net margin or acceptable price of miscanthus at farm gate would remain relatively the same for scenarios having greater yields on higher cost lands.

The determined acceptable price of switchgrass bales at farm gate is $135.7/tonne. The establishment cost of switchgrass is $424.5/acre, and the mature yield is estimated at 4.3 tonne/acre. A decrease in the establishment cost by $100/acre will reduce the acceptable price of switchgrass at farm gate by approximately $5/tonne. The acceptable price of biomass bales at farm gate for Tall Grass Prairie (TGP) and sorghum are $148.7/tonne and $103.9/tonne, respectively. The TGP offers the maximum environmental benefits; however, information on fuel quality of the mixed biomass is limited, and the higher establishment cost and the relatively lower yield could be issues at present. The higher moisture content of current sorghum species at harvest is also an issue in using as feedstock for heat and power generation.

The acceptable price of biomass at farm gate is highly sensitive to the yields of purpose-grown crops. Research and development work in advancing the genetics of purpose-grown crops are relatively at early stages compared to cash crops. Therefore, significant improvements in yields from genetic advancements and crop management should be expected in the next 5-10 years. This would improve the business case of growing purpose-grown crops for energy and other applications.

4.1.2 Biomass Aggregation

There are a few biomass aggregators or pellet mills in Ontario; however, most of them are relatively small with a processing capacity of 1 – 4 tonne/hr. If a purpose-grown biomass industry is to be developed, biomass aggregation is the major supply chain component that needs to be built. Other supply chain components of growing the crops and transportation of biomass are already established to a certain extent. This study investigates the economics of biomass aggregation in terms of processing raw biomass into pellets and transporting biomass from farms to final destinations.

A financial analysis was performed to estimate the total cost of biomass processing, i.e., pelletizing. A pellet mill with a capacity of 150,000 tonne/yr or 20 tonne/hr is considered as an optimum size to draw purpose-grown biomass from 100 km radius. The unit capital cost of agricultural biomass pellets is usually less than that of forestry biomass pellets because a smaller biomass drying system is required. It would cost approximately $15 million to build a 150,000 tonne/yr agricultural biomass pellet mill. The total cost of biomass processing is estimated at $38.88/tonne, which includes the sub-total processing cost of $23/tonne and the financing cost of $15.88/tonne. For this total processing cost of $38.88/tonne, investing in a new agricultural pellet mill would currently provide a return on equity of 17.5%.

Due to strong agricultural and manufacturing sectors, Ontario has a fairly well-developed transportation infrastructure to handle biomass from purpose-grown crops. All modes of transportation, namely truck, rail and marine shipping, are in place to transport goods, including approximately 50 million tonnes of agricultural products (source: OMAFRA crops yields statistics) from and within Ontario. A transportation model was developed in this study based on literature and consultation with industry experts. The model estimates the cost of transporting biomass considering density, moisture, mode of transportation and distance. The total cost of transporting biomass is estimated for three transportation scenarios.

For the centralized heat and power generation system, which usually has a longer total transportation distance, the total cost of biomass transportation in Ontario is $40-50/tonne. The total transportation costs include trucking biomass bales from farm gate to a pellet mill and transporting biomass pellets from the pellet mill to final destination by different modes of transportation. The total distance of biomass transportation for the centralized heat and power generation system is 400-500 km in Ontario. The transportation scenarios with rails or marine shipping have lower transportation costs.

For the distributed heat and power generation system, which has relatively shorter total transportation distance, the total cost of biomass transportation in Ontario is approximately $30/tonne. The total distance of biomass transportation for the distributed heat and power generation system is 200-250 km in Ontario. The cost saving in transportation by rails and marine shipping is unsubstantial due to the shorter total transportation distance.

In the absence of the large scale biomass end users, i.e., centralized heat and power generators, in Ontario, the distributed end users are likely markets for biomass from purpose-grown crops. The total cost of miscanthus and switchgrass pellets to end users are $172.45/tonne and $203.75/tonne, respectively. The total costs include the acceptable price of biomass bales at farm gate, the biomass processing cost and the total transportation cost.

4.1.3 Energy Generation from Biomass

Purpose-grown biomass has to compete with forestry biomass and other energy sources available in Ontario for the generation of heat and power. The cost of these energy sources to the consumers are compared in $/GJ to understand the relative ranking of purpose-grown biomass energy and to identify the potential markets of purpose-grown biomass. The data are collected from the literature, industry statistics and end users and experts.

Miscanthus and switchgrass pellets would cost $9.32/GJ and $11.01/GJ, respectively, to end users. Coal and natural gas are the most competitive fuels in Ontario with approximate costs of $3.5/GJ and $4.5/GJ, respectively. Purpose-grown biomass pellets will not likely have an economic advantage in the areas where coal and natural gas can be accessed and used legally. Space heating applications, where heating oil and propane are currently used, could be potential markets for purpose-grown biomass pellets. The cost of heating oil and propane to end users is approximately $28.42/GJ and $30.58/GJ, respectively. The fuel cost of such space heating applications could be reduced by approximately 65% by switching to biomass pellets.

The potential market of replacing heating oil and propane with purpose-grown biomass fuel needs to be assessed. It would require the detailed investigation of total energy consumptions in those markets, the identification of geographical locations, the distribution of the boiler sizes, and the technology assessment of biomass boilers available locally and abroad. The cost/benefits analysis of replacing different sizes of combustion systems with biomass boilers and accessories should be conducted. The contribution to rural economy from such a replacement and other socio-economic benefits should also be estimated.

Biomass from purpose-grown crops can be the feedstock for both centralized power generators like Ontario Power Generation and distributed energy generators. For centralized electricity-only- generation at current FIT rate of $0.13/kWh, the total cost of purpose-grown biomass pellets would represent a significant percentage, over 85%, of total revenue from the sale of electricity. However, the distributed heat and power generation systems, which likely do not require pelletization and long-distance transportation could be financially viable due to the lower cost of biomass and the sale from heat generated. The distributed heat and power generation system would allow for the integration with other heat demanding agricultural activities, such as vegetable greenhouses.

A financial analysis was performed in this study for distributed heat and power generation using purpose-grown biomass as feedstock. The system considered has an electricity generation capacity of 50 MW and heat generation of 50 MW. The system is assumed to generate base-load electricity and heat that can be sold 4 months in a year. This system could provide heat to approximately 50 acres of vegetable greenhouses. The system will consume about 300,000 tonne/yr of biomass. The total capital cost of such a system is estimated at $175 million. The return on equity for the distributed heat and power generation is 4 – 20%, depending on the cost of biomass and the price of heat.

Europe is currently the largest user of biomass pellets for heat and power generation. The forestry industry in British Columbia has been the prominent supplier of wood pellets to Europe. The European demand for wood pellets is expected to increase from approximately 10 million tonne/yr at present, to 30 – 50 million tonne/yr in next 5 – 10 years. Ontario's forestry industry is interested in accessing the European wood pellet market. The significant increase in European demand for wood pellets could create an opportunity for the agricultural biomass grown in Ontario. Challenges concerning the composition of agricultural biomass exist, however.

The development of a bio-composite material industry could also be beneficial in creating an immediate, alternative market for purpose-grown biomass. Cellulosic bio-fuel and bio-chemicals could be the markets for purpose-grown biomass in the long term since intensive research and development are underway globally. If the development of a purpose-grown biomass industry is to be supported by government, the supports and risk sharing mechanisms should target agricultural biomass. Supports such as the establishment of loans or crop insurance programs are examples of sharing the risks with the farm operators.

4.2 General Recommendations

It is highly desirable to establish a purpose-grown biomass industry in Ontario. This would provide business diversification to Ontario's agricultural producers and offer many soil improvement and other environmental benefits. The following general recommendations are provided to OFA, Erie Innovation and Commercialization and their affiliates:

- Promote biomass production as an alternative crop for Ontario producers.
- Creation of markets for purpose-grown biomass is of critical importance. Biomass use in the space heating applications, where heating oil and propane are currently used, should be assessed in detail as an immediate opportunity.
- Improvements in grain prices in recent years have increased the opportunity cost of farm land in Ontario. Risk-sharing mechanisms, such as establishing loans and crop insurance programs, should be created to support the development of a purpose-grown biomass industry.
- The cost of purpose-grown biomass is highly sensitive to crop yield. Improvement in crop yields due to advances in genetics could substantially reduce the cost of purpose-grown biomass and improve the business case. The investment in the development of high yielding purpose-grown crops should be encouraged.
- Agricultural organizations in Ontario should collaborate with the forestry sector to access the European biomass pellet market, which is rapidly expanding.
- Distributed heat and power generation systems using agricultural biomass as feedstock have a number of benefits. The feasibility of developing a private-public funded demonstration plant, which generates biomass heat and power integrated with other agricultural activities, should be investigated.
- The long-term goal of the purpose-grown biomass industry in Ontario should be the development of local industries manufacturing diverse bio-products. The socio-economic benefits of the purpose-grown biomass industry should be quantified and communicated to policy makers.

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Appendix A – Scope of Work

The Business Case for Agricultural Biomass Use for Heat and Power

This project examines, documents, and reports the economics and business case for the production, aggregation, and utilization, of agricultural biomass (purpose-grown and agricultural residuals) for combustion heat and power. The competitive uses of biomass for fibre, bedding, and chemicals will be part of the economic analysis. The project execution includes regular review meetings with the client and preparation a final report. In the course of these regular review meetings the client can prioritize, adjust, and redirect activities where reasonable within the agreed timeline and scope.

An outline of the project is provided below.

1. Biomass Production Economics
   - Review of biomass production models
   - Land preparation cost
   - Input costs such as seed, fertilizer, and crop protection
   - Harvest, storage, and transport costs
   - Including capital costs, and potential revenues from different market segments
2. Biomass Aggregation Economics
   - Review of biomass aggregation models
   - Transportation cost
   - Storage cost
   - Pelletization and other methods of densification costs
   - Torrefaction cost
   - Including capital costs, and potential revenues from different market segments
3. Biomass Combustion Economics Comparison
   - Cost comparison with coal, natural gas, and oil
   - Recent cost comparison history and near term projections
   - Limited report on the general strengths and weaknesses of biomass versus coal, natural gas and oil
   - Competing alternative uses of biomass such as fibre, bedding, and chemicals
   - Including capital costs, and potential revenues from different market segments
   - Include effects of government subsidies
4. Final Report
   - Provide 5 booklet-format paper copies and an electronic copy of the final report
   - Additional paper copies are offered at the client's cost
   - The report is expected to be about 60 pages including figures, tables, images, and appendices

B1. OMAFRA Budget Worksheet for Hay

Ontario

ALFALFA - TIMOTHY HAY ENTERPRISE BUDGET			Revised: Jan '11		
			Return Per Acre:		$101
Number of Acres =	1				

	Optimistic	Expected	Pessimistic
Yield - tonnes	4	3.5	2.5
Price - $/tonne	125.00	110.00	70.00
Production - tonne	4	4	3
Expected Percent of Harvest in Establishment Year		50%	

Crop Insurance			
C.I. Premium/ac:	9.25	Expected Years of Harvest:	4
Level of Coverage	85%	Current Interest Rate:	4.00%
Guaranteed Yield/ac.	2.98	Current Inflation Rate:	2.00%
Probability of a payout	24.20%		
Expected Payout/ac	$11.79		
Participate in CI? (y/n)	Yes		

		Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
Expenses		-------	------	-	-------	-------
ESTABLISHMENT YEAR COSTS:						
Seed		lbs	16	3.690	59	59
Seed Inoculant		lbs	1	1.050	1	1
Fertilizers						
1.	P	kg	16	1.325	21	21
2.	K	kg	12	1.125	14	14
Herbicides	Glyphosate	ac	1	8.80	9	9
	24D-B	ac	1	15.90	16	16
Crop Insurance		ac	1	2.55	3	3
Custom Work -	Fertilizer Application		2	10.10	20	20
	Pesticide Application		2	10.10	20	20
	Bale wrapping		1	30.85	31	31
Fuel and lubricants		$	1	31.2	31	31
Equip. Repair & Maint.		$	1	19.55	20	20
Labour		$	1	27.5	28	28
General Overhead Costs		$	0	0	0	0
Interest on Oper. Cap.		$	1	9.45	9	9

Total Variable Costs for Establishment						281

Fixed Costs:		Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
Depreciation		$	1	24.9	25	25
Interest on Term Loans		$	1	14.95	15	15
Long-term Leases		$	1	0	0	0
General Fixed Costs		$	1	6.25	6	6

Total Fixed Costs for Establishment						46

TOTAL COSTS FOR ESTABLISHMENT YEAR						327
		Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
ANNUAL PRODUCTION COSTS:		-------	------	-	-------	-------
Contribution to Establishment: Direct Entry				0	35	35
-OR- Amortized over 4 years (Leave Dir. Entry at 0)						---
Fertilizers:						
1.	P	kg or l	0	1.325	0	0
2.	K	kg or l	52	1.125	59	59
3.	________________	kg or l	0	0.000	0	0
Pesticides:						
1.	________________	kg or l	0	0.00	0	0
2.	________________	kg or l	0	0.00	0	0
		Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
Other Expenses:		-------	------	-	-------	-------
Crop Insurance		Insurance	1	9.25	9	9
Twine		bale	0	0.00	0	0
Other		$	0	0.00	0	0
Custom Work, Rentals:						
Fertilizer application		$	2	10.10	20	20
Bale wrapping		no.	7.71	8.00	62	62

Go to General Costs Allocation Worksheet

		Typical $/Acre	$/Acre	$/Year
Fuel		18.85	19	19
Mach. Repair & Maint.		14.9	15	15
Bldg. Repair & Maint.		0	0	0
Labour		26.25	26	26
General Variable Costs		0	0	0
Interest on	%int	%year		
Operating Capital	4	50	4	4
			-------	-------
Total Variable Costs			249	249
Fixed Costs:		Typical $/Acre	$/Acre	$/Year
Depreciation		19	19	19
Interest on Term Loans		11.4	11	11
Land Cost		-	0	0
Long-term Leases		0	0	0
General Fixed Costs		4.75	5	5
			-------	-------
Total Fixed Costs			35	35

Revenues:	$/Acre	$/Year	
Total Expected Revenues	385	385	
less: Variable Costs	249	249	
	-------	-------	
Expected Operating Margin	136	136	
less: Fixed Costs	35	35	
	-------	-------	
Expected Net Revenue	101	101	

Break-even $/qt to cover:	Variable Costs	71.14
	Fixed Costs	10.04

	Total Costs	81.18

Chance of at least breaking even		==>	75%	
Chance of at least	0	$/acre return ==>	75%	
Risk Indicator - Coefficient of variation		==>	0.39	Moderate Risk

Returns $/acre	Chances of at least this return per acre
246	17 %
165	33 %
101	50 %
37	67 %
-44	83 %

The user of this worksheet assumes all responsibility.

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B2. OMAFRA Budget Worksheet for Switchgrass

Ontario	SWITCHGRASS ENTERPRISE BUDGET		Revised: Oct '09
		Return Per Acre:	($224)
Number of Acres =	1		

	Optimistic	Expected	Pessimistic
Yield - tonnes	3.7	3.1	2.5
Price - $/tonne	-	-	-
Production - tonne	3.70	3.10	2.50

Expected Years of Harvest:	10
Current Interest Rate:	5.00%
Current Inflation Rate:	2.00%

		Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
Expenses		-------	------	-	-------	-------
ESTABLISHMENT YEAR COSTS[1]:						
Seed - Pure Live Seed[4]		lbs	15	9.000	135	135
Seed Inoculant			0	0.000	0	0
Fertilizers						
1.	N	kg	2.7	1.180	3	3
2.	P	kg	11	0.840	9	9
3.	K	kg	11	1.220	13	13
Herbicides[5]	Burndown[2]	$	1	20.00	20	20
	Annual grass/ broadleaf	$	1	28.00	28	28
Crop Insurance		$	0	0.00	0	0
Custom Work[3] -	Fertilizer Application		0	9.05	0	0
	Pesticide Application		2	9.05	18	18
	Other		0	0.00	0	0
Fuel and lubricants[3]		$	1	10.6	11	11
Equip. Repair & Maint.[3]		$	1	11.85	12	12
Labour[3]		$	1	12.95	13	13
General Overhead Costs		$	0	0	0	0
Interest on Oper. Cap.		$	1	6.25	6	6
					-------	-------
Total Variable Costs for Establishment					269	269

Fixed Costs:	Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
Depreciation[3]	$	1	23.7	24	24
Interest on Term Loans[3]	$	1	16.4	16	16
Land costs[6]	$	1	30	30	30
Establishment failure rate[7]	%	10		34	34
General Fixed Costs[3]	$	1	3.95	4	4
				-------	-------
Total Fixed Costs for Establishment				108	108
				-------	-------
TOTAL COSTS FOR ESTABLISHMENT YEAR				377	377
	Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
ANNUAL PRODUCTION COSTS:	-------	------	-	-------	-------
Contribution to Establishment[9]: Direct Entry			0	44	44
-OR- Amortized over 10 years (Leave Dir. Entry at 0)					---
Fertilizers[10,12]:					
1. N	kg	27	1.180	32	32
2. P	kg	6	0.840	5	5
3. K	kg	4	1.220	5	5
Pesticides:					
1. ____________	kg or l	0	0.00	0	0
2. ____________	kg or l	0	0.00	0	0
	Unit/Ac	Number	Cost/Unit	$/Acre	$/Year
Other Expenses:	-------	------	-	-------	-------
Crop Insurance	Insurance	0	10.05	0	0
Twine	bale	0	0.00	0	0
Removal from field and storage[13]	tonne	3.1	6.60	20	20
Custom Work[3]:					
Fertilizer application	$	1	9.05	9	9
Pesticide application	$	0	0.00	0	0

Go to General Costs Allocation Worksheet		Typical $/Acre	$/Acre	$/Year
Fuel[3]		13.05	13	13
Mach. Repair & Maint.[3]		11.45	11	11
Bldg. Repair & Maint.		0	0	0
Labour[3]		15.65	16	16
General Variable Costs		0	0	0
Interest on	%int	%year		
Operating Capital	3.25	50	2	2
			-------	-------
Total Variable Costs			158	158

Fixed Costs:	Typical $/Acre	$/Acre	$/Year
Depreciation[3]	19.45	19	19
Interest on Term Loans[3]	13.45	13	13
Land Costs[8]	30	30	30
Long-term Leases	0	0	0
General Fixed Costs[3]	3.25	3	3
		-------	-------
Total Fixed Costs		66	66

Revenues:	$/Acre	$/Year
Total Expected Revenues	0	0
less: Variable Costs	158	158
	-------	-------
Expected Operating Margin	-158	-158
less: Fixed Costs	66	66
	-------	-------
Expected Net Revenue	-224	-224

Break-even $/tonne to cover:	Variable Costs	50.85
	Fixed Costs	21.34

	Total Costs	72.19

Chance of at least breaking even		==>	#DIV/0!
Chance of at least	0	$/acre return ==>	#DIV/0!
Coefficient of variation		==>	#DIV/0!

Returns $/acre	Chances of at least this return per acre
-224	17 %
-224	33 %
-224	50 %
-224	67 %
-224	83 %

Assumptions

Note – Assumptions made for the purpose of this budget (costs, yields, etc) are estimates for discussion only, and will change according to research, agronomics and economic conditions. Users should make their own assumptions. As switchgrass is a new commercial crop in Ontario, considerable research and field experience is required in order to answer many of the agronomic and economic questions being asked. Assumptions made in these budget estimates are not to be considered recommendations.

1. Establishment using conventional tillage. No-till establishment may be more practical on some land due to slope and stoniness. No-till establishment may be less reliable, so further research is required.

2. Field prep for establishment of switchgrass with a glyphoste burndown may have to be done twice (fall & spring) in excessively weedy fields, doubling these costs (equivalent to approximately $1/tonne).

3. Field operation costs (spraying, plowing, cultivating, seeding, fertilizer spreading, swathing and baling) have been estimated from commercial custom rates (OMAFRA Factsheet #07-019 "Guide To Custom Farmwork") and market conditions.

4. Seed costs may change according to supply and demand as a seed industry develops. Seeding rate recommendations may change based on further research.

5. No herbicides are currently registered for use on switchgrass in Ontario. Product registration of herbicides will be required before commercial use. Research is currently being done by the University of Guelph. Recommended products, rates and costs will depend on research results.

6. "Establishment year land cost" is used to account for slow establishment that will likely result in no product to sell for the first year. Second year yields may only be approximately 50% of the stand average, which has been accounted for in the 3.1 tonne/ac 10 year average. This estimate assumes:

   direct seeded as opposed to using a cereal companion crop

   a minimum $30 per year return to land (rental rate opportunity cost).

7. "Establishment failure rate" is used to account for unsuccessful establishment 1 time out of 10. This is only an estimate for discussion and will require research and field experience to establish a more accurate number.

8. Land costs have the potential to be extremely variable, depending on factors such as location, drainage, slope, and the economics of other land uses, such as other crops and cattle. Land may be available at lower value, but with lower yield potential.

9. The establishment costs will need to be recovered over the productive life. The costs are amortized at an interest rate of 5% over 10 production years. This will vary widely, depending on agronomic factors such as establishment success and yield, and economic factors such as alternate crop opportunities.

10. Research is required to determine appropriate N rates based on yield response.
11. Yield estimate at 3.1 tonnes/acre are based on a fall cut - spring harvest system. Yields are potentially higher with a fall harvest, but with higher ash content and phosphorus (P) & potassium (K) removal rates. Yields will vary widely depending on agronomics and environmental conditions. An estimate will be become more accurate with further field experience in Ontario.

12. P & K "removal rates" assume a spring harvest system where significant mineral leaching has occurred. This example assumes removal of 4.0 lbs P_2O_5 per tonne @ 55¢/lb, and 2.9 lbs K_2O per tonne @ 55¢/lb, which is equivalent to about $3.80 per tonne. Using "removal rates" for P & K assumes that fertility levels are not yield limiting, and therefore likely in the "Medium" soil test range. Some of the targeted acreage could be more marginal in fertility and require higher fertilizer application rates.

13. "Removal & storage" estimates reflect the cost of moving bales off the field and into storage (building or on skids and under a tarp).

14. Hauling – if the processing plant is pricing based on FOB the plant, trucking costs will need to be included to haul from storage to the plant

15. In order to attract producers, farmers will expect a "Return To Risk & Management" in addition to the COP. This will vary with individual producers, depending on the profitability and risks associated with other crops and investments.

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The user of this worksheet assumes all responsibility.

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Appendix C – Major Natural Gas Pipelines in Ontario

Source: http://atlas.nrcan.gc.ca/site/english/maps/economic/transportation/pm_pipelines

Ontario

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