Switchgrass Fuel Pellet Production In Eastern Ontario: A Market Study

A Small Projects Initiative
Funded under CANADAPT and
The Agricultural Adaptation Council of Ontario

Final Report

By

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December, 2001

Executive Summary

Following successful switchgrass field production and laboratory pelleting trials, a market study for developing a switchgrass pellet fuel industry in eastern Ontario was conducted by REAP-Canada in 2001. The study consisted of, (1) a farmer survey and focus group meetings, (2) a land availability assessment and (3) an analysis of the current wood pellet industry and energy markets. The work took place between February and November, 2001.

The farmer survey revealed interest from a broad spectrum of economic backgrounds ranging from hobby farmers and market gardeners to dairy farmers and corporate hog farming operations with over 2000 acres of crops. Interest in grass pellet heating stemmed from a desire to decrease on-farm energy costs, to increase energy self-reliance, to diversify on-farm income, to better utilize marginal lands and to create employment associated with pellet processing and distribution. Reducing fossil fuel use and greenhouse gas (GHG) emissions were also important factors. The greatest perceived risks were slow uptake of pellet stove heating, poor demand for switchgrass pellets, big bale storage fire and insufficient pelleting infrastructure. Preference was expressed for mobile pelleting systems. Farmers were cautious about committing to grow switchgrass without more information on pellet prices, heating costs and market size. A clear need for demonstration heating projects was identified.

Retailers reported strong pellet stove sales in 2000-2001. They were very supportive of developing a new pellet fuel to augment increasingly tight and costly supplies of wood pellets, provided high pellet quality could be achieved. Concern was expressed about (1) the small number of Canadian pellet stove manufacturers, (2) the higher ash content of switchgrass relative to wood and (3) the limited number of stoves able to efficiently burn these pellets without clinker (fused residues) build-up.

There is a large area of agricultural and forest land suitable for switchgrass production in eastern Ontario. The soils are predominantly well drained but include some clay. About 247,000 acres (100,000 ha) of agricultural land could be converted in eastern Ontario with an additional 116,000 acres (47,000 ha) and 333,500 (135,000 ha) available in central and western Ontario, respectively. Land rents of $60/a (about $15/tonne) were identified as the maximum threshold for economic switchgrass production. Large areas of farmland in eastern Ontario rent for less than $60/acre. Five regions in eastern Ontario were identified with potential to supply a 50-100,000 tonne pellet plant: (a) Prescott County and the Alfred area, (b) Renfrew County ranging from Arnprior to Pembroke (c) Lanark County and the Lanark Highlands, (d) Peterborough County ranging from Lindsay and Hastings, and (e) Prince Edward County. If energy prices increase more quickly relative to land prices, then switchgrass production could be feasible on higher value land in other regions of Ontario.

Wood pellet heating systems are considered an essential component of Europe's alternate energy and GHG reduction strategy. Expansion of the wood pellet industry in Canada is limited by a lack of surplus wood residues. Existing alfalfa dehydration and wood

pelleting facilities in Ontario have the capacity to pelletize a minimum of 10,000 additional tonnes of feedstock. Production on this scale would support the early commercialization phase of a biofuel pellet industry. The investment to construct a dedicated pellet plant with a annual output between 50,000 and 100,000 tonnes ranges between $2 –7 million depending on specifications.

Costs for switchgrass should follow the same trend as stagnant, long-term agricultural commodity prices and remain lower, and fluctuate less, than fossil fuel prices. The incorporation of close coupled gasification technology in pellet stoves produced by Dell Point Technologies enables the combustion of moderately high ash fuels such as switchgrass at efficiencies of 80-85% The cost of heating a 2000 ft^2 home with switchgrass pellets using a Dell-Point 34,000 BTU space heater is $1213 compared to $2234, $1664, $882 and $2302 for electricity, heating oil, natural gas and propane, respectively. The development of pellet furnaces with outputs of between 250,000 and 1 million BTUs will make pellet heating systems appropriate for a broad range of structures including farm buildings, livestock barns and greenhouses.

Heating with switchgrass pellets would reduce carbon dioxide emissions by 86-91% compared to conventional energy sources. The decrease could generate at least $36 million of additional revenues by way of carbon emission credits if switchgrass pellets were produced from the currently available land area in eastern Ontario. The same volume of pellets could meet 18% of the current demand for electricity, oil and propane used for domestic space heating in the province. The farm gate value would be approximately $63 million. The value of pellets is estimated at $158 million. It is anticipated that the economics of switchgrass pellet heating systems will improve as fossil fuel prices and energy consumption in Ontario rise.

The European wood pellet industry is a model of how biofuel pellets can evolve from the developmental stage to a modern and efficient energy system in a short period of time. An emphasis on public information, customer convenience, government support and buy-in by conventional energy companies has enabled the pellet industry to overcome barriers and challenges and compete with conventional energy sources. Bulk handling and automated delivery provide a convenience level similar to liquid fuels.

The potential for a switchgrass pellet industry in Ontario is substantial, but the pace of development depends, in part, on energy prices and government’s commitment to reducing GHG emissions. The short-term outlook for market expansion is modest due to the lack of feedstock and limited number of pellet stoves on the market. In the medium-term, the development of larger output pellet burners should expand the range of application and significantly increase demand for pellets. The combined implementation of domestic and on-farm heating systems could generate a demand for 20,000 tonnes of pellets annually within 5 years. In the long-term, switchgrass pellets will become more competitive as fossil fuel prices increase. Incentive programs are needed to establish demonstration pellet heating systems and to increase public awareness about the economic and environmental benefits from a switchgrass pellet fuel industry and to continue research in improving mobile pellet systems and pellet quality.

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General Introduction

The following study is based on almost 10 years of research by REAP (Resource Efficient Agricultural Production) - Canada on the potential for growing biomass for paper and energy production in Ontario. Two previous studies on switchgrass production were funded by the Small Projects Initiative and the CanAdapt Program: Switchgrass Plant Improvement for Paper and Agri-fibre Production in Eastern Canada (Phase I & II). Several years ago REAP conducted successful laboratory trials investigating the processing qualities of switchgrass and a variety of other herbaceous feedstocks into biofuel pellets were followed by a commercial-scale pellet run at an alfalfa dehydration plant in Ste. Marthe, Quebec, in December, 2001. At this time, Dell-Point Technologies announced it was incorporating close coupled gasification technology in its line of pellet stoves making it possible to efficiently burn switchgrass, as well as wood pellets.

The years 2000 and 2001 were punctuated by considerable fluctuations in energy prices and increasing concerns about the security of domestic Canadian energy supplies. In addition, increasing attempts are being made by the agricultural sector to develop non-food uses for agricultural crops. Energy production is now an area of keen interest. The recent ratification of the Kyoto Protocol has further heightened interest in biofuels as a greenhouse gas mitigation strategy. These factors have combined to make biofuel pellet production from perennial grasses a significant research and development opportunity.

Over the past decade there has been considerable research effort directed at increasing supplies of alternate sources of biofuels such as wood fibre from plantation forestry. Development of efficient energy conversion technology, however, has often lagged behind. The development of switchrass biofuel pellets as a clean burning energy option is unique because it coincides with the development of efficient combustion technology for moderate high ash pellet fuels. For this reason, it was seen as appropriate to conduct a market study on pellet fuel heating industry for eastern Ontario.

This report is divided into three parts. Section One reports on the results of a farmer survey and series of focus group meetings conducted in Eastern Ontario between January and August, 2001. Section Two provides an assessment of the availability of land for switchgrass production in Ontario. Section Three focuses on the market potential and economic factor surrounding a switchgrass pellet heating industry in Ontario.

Task 1. Farmer surveys and focus group meetings

1.1 Introduction

A series of meetings were held between January and August, 2001, to engage farmers in promising areas for switchgrass production in eastern Ontario. The meetings were designed to increase awareness about the potential for a switchgrass pellet fuel industry and to identify factors influencing producers' decisions to be involved. Participants were provided with information packages describing production practices and costs, as well as recent developments in pellet stove technology and pellet production. A survey was distributed to interested farmers to seek feedback on, (1) land opportunities, (2) cost of production and profit margins, (3) on-farm energy costs, (4) expected use of pellets, (5) pelleting facilities and (6) risks and support for the industry. Additional information was collected from telephone interviews and electronic communications with individuals made aware of REAP's research from television and radio interviews, newspaper articles and the REAP website. Pellet stove dealers and pellet distributors, as well as alfalfa and wood pellet processors, were also interviewed to obtain information about processing operations and the wood pellet market. The results of the survey are described below and integrated into Sections 2&3 of this report.

1.2 Methodology

Farmer survey

A survey (Appendix 1) was distributed to farmers in eastern and central Ontario between January and August, 2001, to assess the level of interest and capacity within the farm community to support a switchgrass pellet industry. Additional surveys were distributed at focus group meetings (see below) and interested individuals. A newspaper article accompanied by a request for survey participants was published in the Ecological Farmers Association of Ontario Spring, 2001, newsletter (membership 600). Survey forms and information packages were also distributed at the Guelph Organic Conference, January 26-28, 2001. In total, 325 survey forms were distributed and 33 forms were completed and returned. The response rate was 10%.

Focus groups

A series of seven focus group meetings were held between March and August, 2001. Five meetings took place in conjunction with farming conferences and crop field days in eastern Ontario because these were viewed as the best opportunity to contact larger groups of farmers. The focus group meetings took place at: (1) Eastern Ontario Crop Conference, Kemptville, February 23, (2) Eco Farm Days, Morrisburg, Feb. 24, (3) Technology and Innovation Days, Alfred, April 3-4 and (4) Rural Agri-Ventures-Ontario Conference and Tradeshow, Campbellford, April 28-29 (two sessions). The number of meetings was increased from four (as originally planned) to compensate for poor conference attendance at the Kemptville and Alfred events. Smaller focus group meetings were held with the Ottawa Stewardship Council, Manotick, April 24, (5 farmers, 6 landowners), and "kitchen table" style meetings were held in Williamsburg, Aug. 3, (2 farmers) and New Hamburg, Aug. 4, (4 farmers). Supplementary information was collected from conversations with growers who currently have established switchgrass plantations in Ontario.

Stove dealers and pellet distributors

Three major pellet and wood stove retailers and two wood pellet distributors in eastern Ontario were interviewed about the current state of the wood pellet industry and pellet heating technology. Wood pellet processors were interviewed from across Ontario, Quebec and Atlantic Canada.

1.3 Survey results

1.3.1 General Summary

A total of 33 survey forms were completed. Hay and cash crop farmers were the largest response group (8). Hog producers (6), dairymen (4), beef producers (4), mixed crop and livestock farmers (3), vegetable growers (3), greenhouse operators (2), and other farmers (3) also participated. One respondent owned an alfalfa pellet mill and another distributed wood pellets. A number of cash crop farmers ran beef as a sideline. About 70% of the respondents farmed in eastern Ontario (23) while four farmed in central Ontario, two in southwest Ontario and one in northern Ontario. Three producers farmed in Quebec (Table 1.1). Four organic farmers completed the survey. Although rising energy costs are a major concern within the farming community, awareness about pellet heating options was low. Consequently, fewer surveys were completed than originally expected. It was also clear that an individual's expression of interest in a technology does not necessarily translate into a commitment to complete a survey form.

- **Farm Size.** Two thirds of the respondents farmed more than 100 acres. Production ranged from small market gardens to 2000 acre mixed livestock and cash crop farms. Respondents represented a broad range of economic interests from individuals aspiring to self-sufficiency to corporate farming operations.

- **Land Rents.** Land rents ranged from $200 per acre to "no charge" depending on location. As expected, land in southwest Ontario was the most expensive ranging from $75-175 per acre. Land costs in central Ontario (Guelph/Waterloo) were $30-200 per acre, in eastern Ontario $35-100 per acre and $50-100 per acre in Quebec. One farmer near Ottawa reported that land in his neighbourhood rented for $200 per acre. The majority of the land identified by respondents as being available for switchgrass production cost less than $65 per acre.

- **Intended Use.** Intended uses for pellets included residential, barn, shop and greenhouse heating, and off-farm exports. Switchgrass was also proposed as a source of livestock bedding, a substrate for mushroom compost and garden mulch. Organic farmers identified switchgrass as a promising crop for buffer zones between organic and conventional crops.

- **Pelleting System.** Most respondents favoured mobile pelleting units over stationary plants as a tool to reduce transportation costs. Many were hesitant about stating a preference because they lacked knowledge about pelleting technology.

- **Storage Capacity.** Most farms had facilities for big bale storage. Pellet storage was also available on some farms in grain bins. There was considerable interest in bulk pellet handling to eliminate bagging costs.

- **Perceived Risks.** The greatest risks associated with developing a pellet industry were slow uptake of pellet stove heating, poor demand for pellets, big bale storage fires and the ability to develop an economical transport and pelleting infrastructure.

- **Expected Returns.** Respondents were non-specific about expected returns per acre. The priority for most respondents was to develop energy self-reliance and reduce on-farm energy costs. Others stressed the importance of reducing dependence on fossil fuels for environmental reasons. Those wishing to export switchgrass expected a return similar to that of a hay crop.

- **Support services** requested for industry start-up included financial assistance for infrastructure development, crop insurance, technical support for crop establishment and management and financial incentives for homeowners willing to convert to non-fossil fuel heating systems.

- **Interest** in pellet production and heating systems stemmed from a desire to decrease on-farm energy costs, to increase energy self-reliance and certainty of supply, diversify farm income and better utilize marginal lands. Hog farmers questioned whether switchgrass could double as a sink for hog manure and as a fuel source for heating hog barns. Propane is currently widely used for heating hog barns, but recently the converted energy costs have been similar to electricity.

Table 1.1. Summary information from the farmer survey.

Farm Type	#	Region	Landbase (acres)	Land rents ($/a)	Soil type	Bale Storage	Intended Use	Pelleting System
Dairy	1 1 1 1	**SW. Ontario** E. Ontario N. Ontario Quebec	270 460 500 150	75-150 65 10	Sandy loam Loam Clay loam Loam	Yes Yes Yes Yes	Residential Bedding Farm fuel Farm fuel/export	Mobile Mobile Mobile Depends
Hog	5 1	E. Ontario Ctr. Ontario	30-2600 100-300	15-50 120	Clay-clay loam Clay loam	Yes Yes	Barns, residential, bedding, farm shop Barns, residential	Mobile to Depends
Beef	4	E. Ontario	50-250	not sure	Sand, sandy loam, clay Loam, clay	Yes	Residential, export, shop	Mobile to depends
Cash Crop	6 1 1	E. Ontario Ctr. Ontario N. Ontario	12-2000 1900 250	33-100 30-70 35	Cl. loam/sand Guelph loam Sandy	most	Residential, export Residential , dryer Residential, export	Mobile, but many unsure
Mixed	1 1 1	E. Ontario Ctr. Ontario Quebec	15 115	50 200 100	Clay loam Clay Clay loam	No No No	Residential, gr. house Residential Residential, barn, shop	 Mobile Mobile
Vegetable	3	E. Ontario	3-55	0-50	Clay-sand	No	Residence, mulch, gr. house	Mobile
Greenhouse	1 1	SW. Ontario Quebec	20 10	150-175 50	Sandy loam Sandy loam	Yes No	Residential, Gr.house Gr.house	Mobile Mobile
Other	1 1 1	E. Ontario Ctr. Ontario E. Ontario	10 100+ 10	25 95-150 120-150	 mixed clay	No Yes Yes	residential Pelletize for sale Residential, shop	Mobile Own pelleter The cheapest

1.3.2 Focus group meetings

Focus groups ranged from formal presentations and question and answer sessions within a field day/conference setting to informal 'kitchen table" discussions on individual farms. About 95 people were engaged in direct focus group discussions with additional conversations held with conference and field day attendees. More people participated in focus group meetings than expected. Participants can be broadly categorized as either potential pellet producers or potential pellet users. Farmers most often fell in both categories.

1.3.3 Responses from potential pellet producers

A switchgrass pellet heating industry was viewed as a potential boon to rural farming communities because feedstock production could make use of marginal farm land and surplus production area, diversify farm income, generate employment in pellet plants and buffer farmers from fluctuating energy prices.

Production aspects identified as positive were the low fertilizer and herbicide requirements of switchgrass. Concern was raised whether switchgrass was an invasive species because it is sometimes confused with twitch grass (*Agropyron repens*). Switchgrass does not spread by rhizomes and is considered non-invasive. The possible effect of spring harvesting on wildlife populations was also raised. Farmers expressed concern about weed control and feedstock transport costs.

Several producers questioned whether switchgrass would thrive on heavy and imperfectly drained soils – land typically classified as marginal. The capacity for these soils to support tillage and harvest equipment was also questioned. Although switchgrass will tolerate occasional flooding, it is not adapted to cold wet soils. Both fall and spring harvesting – depending on timing and the season – may be complicated by wet field conditions. Farmers should choose fields for switchgrass production accordingly.

One group of farmers in the Waterloo area recognized the need to develop cleaner burning, alternatives to fossil fuels. They were willing to consider growing switchgrass on a portion of their land even though land costs were above the $60 per acre generally considered viable for switchgrass pellet production. Hog farmers in the group felt they could reduce fertilizer costs by fertilizing switchgrass with hog manure. They acknowledged that the addition of extra phosphorous and potassium might raise ash levels in the feedstock.

The most common question was whether a market for switchgrass pellets currently existed. Farmers expressed hesitation about investing in the crop before a reliable market for pellets was established. Some were reassured that alternate markets for switchgrass, including livestock bedding, compost substrate for mushroom production, and possibly as a feedstock for cellulosic ethanol production, would reduce risk during the industry start-up phase. Participants were supportive of switchgrass pellet heating systems and recognized the economic and environmental benefits of the crop. Some were familiar with the unrealized potential of the hemp market and were cautious about producing unconventional crops.

1.3.4 Responses from potential pellet users

The majority of potential pellet users identified in the study were farmers. Some had familiarity with wood pellet heating systems, but grass biofuel pellets were a new concept. Participants were impressed by the high efficiency of the Dell-Point stove, the only pellet stove on the market (manufactured in Canada) using close coupled gasification technology and capable of burning switchgrass, wood and bark pellets and corn at 80-85% efficiency. Further advantages identified included avoiding the need for an expensive chimney and increasing energy self-sufficiency without relying on wood. Firewood was seen as increasingly expensive and hard to handle.

Poor experiences with corn stoves and the need for electricity to power pellet stove augers and fans caused farmers to express caution about the technology. The $3100 cost of a Dell-Point stove was seen as a potential barrier to adopting a switchgrass pellet heating system. Most homeowners had a primary heating system currently in place. Residential space heating was the most commonly identified use for switchgrass pellets, but many farmers were interested in installing pellet furnaces and boiler systems for larger applications like livestock barns, outbuildings and greenhouses.

Numerous individuals commented that even though fossil energy prices are currently stable, they were interested in energy self-reliance to avoid future price fluctuations and what they perceived as "price gouging" practices by energy companies. Environmental benefits stemming from biofuel use and CO_2 emission reductions were also contributing factors. The majority did not feel that feeding stoves manually with fuel was an inconvenience. Respondents stressed the need for heating demonstration projects to increase awareness and knowledge about the technology

Both producers and users wanted more firm figures on pellet prices and heating costs before making production or purchasing commitments. They also questioned the length of the payback period for pellet stoves (see Task 3).

Current wood pellet users live in both urban and rural areas with a greater concentration in regions without natural gas service. High gas prices in 2000-2001 increased the proportion of urban pellet users. Wood pellets can be purchased at stove dealers, nurseries, building supply stores, feed stores and some discount merchandisers. Pellets are usually packaged in 20 kg bags and sold by the bag, or by the tonne (fifty shrink- wrapped bags on a shipping pallet).

1.3.5 Comments from pellet stove dealers

Pellet stove dealers reported a "resurgence" in sales during 2000-2001 due to high fossil energy prices. However, they were cautious about forecasting a rapid shift to pellet stove heating systems. Wood pellet stoves have been on the market for less than ten years and problems with product service, inconsistent pellet supplies and unrealistic claims over product efficiency have dampened initial enthusiasm for the technology. The poor reputation of corn stoves (metal corrosion, poor efficiency) has also hurt sales. Dependence on the electrical grid for the pellet feeding auger and circulating fans was also viewed as a disadvantage during the "ice storm" in 1997. Some dealers were reluctant to promote pellet stoves until these barriers were overcome. Others were more enthusiastic and suggested more effort was required to promote and advertise what were generally efficient and reliable products.

Concern was expressed about, (1) the small number of Canadian pellet stove manufacturers, (2) the high cost of units imported from the U.S. and (3) the willingness and ability of manufacturers to make technical improvements according to customer experience. All the stove dealers expressed concern about the higher ash content of switchgrass compared to wood pellets and the limited number of stoves able to efficiently burn these pellets without clinker (fused residues) build-up. Two dealers were concerned that the combustion efficiency of switchgrass pellets was based on a proprietary technology incorporated in a single stove type (the Dell-Point model; www.pelletstove.com). They suggested that widespread introduction of switchgrass pellet heating depended on having more competitors manufacturing stoves and furnaces incorporating close coupled gasification technology.

Dealers were very supportive of the development of a new pellet fuel to augment increasingly tight and costly supplies of wood pellets. They emphasized the need for high pellet quality. Additional needs included increased hopper capacity, greater ease of cleaning, greater ash capacity and thermostatic operation. Dealers saw a great potential for larger capacity heating units such as pellet furnaces and boiler systems for central heating and greenhouse applications.

1.3.6 Comments from pellet distributors

Two pellet distributors in Smith Falls and Ottawa expressed concern about the growing shortage of wood pellets and deteriorating wood and pellet quality. Both were farmers and distributors for Harman wood pellet stoves. They cited the diminishing supply of sawdust in eastern Canada as the primary reason for the pellet shortage. A greater proportion of bark pellets were sold during 2000-2001. Some individuals were mixing pellets made from sawdust (#1 grade) with bark pellets (#2 grade) to avoid clinker (fused residues) formation in the stove.

One distributor commented that some customers preferred not to use natural gas because of perceived danger and high heating costs. Some reasons for chosing pellet heating included, (1) the desire for an even flow of heat, (2) elimination of the need for an additional chimney and (3) environmental preferences (reduced greenhouse gas and particulate emissions compared to fossil fuels and roundwood).

The same individual explained he had previously tried to grow corn to supply customers with corn stoves, but that initiative failed due to poor demand. He is now planning to establish a small switchgrass plantation and to process pellets (on a trial basis) in order to assess the feasibility of marketing his own fuel. He is considering selling the Dell-Point pellet stove because of its high efficiency.

1.4 Conclusion

The market survey indicated that support for developing a switchgrass pellet fuel industry was strong across a broad spectrum of the farming community ranging from hobby farmers to corporate hog farmers. The response group was not restricted to "green" or alternative-minded farmers or consumers. Prior to the study, awareness about grass pellet heating systems was low. The farmer survey and focus group sessions increased the level of knowledge about the technology and raised a number of advantages and concerns seen by individuals as central to the successful development of the industry.

A broad range of applications for switchgrass pellet heating systems were identified, including residential and on-farm heating and off-farm pellet exports. Mobile pelleting units (if available) were perceived as preferable over centrally located plants to reduce transportation costs. Farmers were preoccupied with reducing heating costs and increasing energy self-reliance rather than realizing specific monetary returns per acre. This attitude could shift with development of the industry to increased off-farm pellet exports.

A switchgrass pellet industry was seen as a potential boon to farming communities, but farmers wanted more data on the depth of the switchgrass pellet market before committing large land areas to switchgrass production. Risk sharing with government was viewed as necessary to help potential switchgrass growers enter the market. Incentive programs for purchasing domestic-scale pellet stoves would stimulate technology adoption and demand for switchgrass pellets. Current federal programs such as the Renewable Energy Deployment Initiative (REDI) program are targeted at larger scale, commercial applications. More rapid market development would occur with the development of larger production units such as pellet furnaces installed for central heating in detached homes or as primary heating systems for livestock barns, workshops and greenhouses. Focus group participants were looking for incentives from government to facilitate infrastructure and market development.

Stove dealers expressed some uncertainty about introducing both a new fuel type and a relatively new combustion technology to the heating market at the same time. Recommendations for industry start-up include an effective consumer information program, a product service plan from manufacturers and a broad-based appliance distribution network. Dealers identified a strong need for larger capacity combustion units to meet the growing demand for economical and environmentally friendly space heating systems for domestic and commercial/industrial applications. A clear need was identified for demonstration pellet heating projects to increase awareness and knowledge about the technology.

II. Assessment of land availability

2.1 Introduction

The development of a pellet fuel industry in Ontario depends in part on a sufficient land base for switchgrass production. Systems of land use classification vary in the province. These range from detailed descriptions of soil types to agricultural land use statistics by crop type. Three different approaches were used in this study to estimate land availability for switchgrass production:

- A primary land assessment was developed by REAP-Canada for Eastern Ontario which mapped all soils, including forested areas, according to physical properties. These were then rated for their suitability for growing switchgrass.

- A second assessment was developed using current field crop statistics and estimating the area of land which could be converted from conventional crops to switchgrass.

- A third method identified regions in the province with a concentrated area of land presumed large enough to supply feedstock to a pellet plant dedicated to processing switchgrass.

Information from the three scenarios were integrated with knowledge of land values, hay prices and soil quality from producers and regional farm management specialists. Eastern Ontario is the main focus area of this study because of the large amount of underutilized land and low land values. Additional information is presented for central and western Ontario.

2.2 Methodology

2.2.1. Study 1: Soil matrix and land suitability map

The main goal of this study was to describe the land base of eastern Ontario in terms of soil suitability for switchgrass production. This was achieved by:

A - Developing a soil suitability matrix for switchgrass
B - Developing a soil suitability map for eastern Ontario

A - Soil Suitability Matrix

The soil suitability matrix (i.e. a soil rating scheme) for switchgrass includes five soil factors: percent coarse fragment, slope, rooting depth, drainage, and soil texture. For each soil factor, its suitability for switchgrass production was rated as "good", "fair", "poor", or "unsuitable". The matrix for switchgrass was based on a model developed for hemp production by Francis (1996), which used classifications for corn, spring cereals and perennial forage crops such as alfalfa and timothy. These classifications were combined with observations and information collected by REAP-Canada for switchgrass in eastern Canada between 1993-2001, as well as information from the US switchgrass development program Four basic guidelines were used to define the rating scheme:

1) Switchgrass can be grown on land having more acute slopes than possible for annual crops because of permanent soil cover which limits soil erosion;
2) Switchgrass can be grown on more moisture-limited soils than conventional cash crops because of its deep root system;
3) Soil textures which are good, fair, poor and unsuitable for switchgrass production are:
   - good: loams in connection with gravel, sand, or silt
   - fair: sands, clays, gravels
   - poor: heavy clay, very gravelly loam sand and very gravelly sand

- unsuitable: peat (organic soils)

4) In cases where information was limited, a conservative rating was applied.

B - Soil Suitability Map

The data required to produce the soil suitability maps were obtained from the Soil Landscapes of Canada Survey. All files were downloaded from the CanSIS web site. The data set, based on hundreds of polygons, was interpreted to determine where switchgrass could be grown in eastern Ontario. A polygon is an area on a map described by a standard set of attributes such as soil surface form, texture, slope, water table depth, etc. (Agriculture Canada, 1997). The matrix developed in the previous section was used to rate the polygons according to their suitability for switchgrass production.

Each polygon was rated according to the soil suitability matrix as "good", "fair", "poor", or "unsuitable". If all conditions were "good", then the polygon was rated "good". The lower class dominates the classification. If there were one or two "fair" or "poor" ratings then the polygon was assigned "fair" or "poor" along with a letter code to denote the limitations. Three or more "fair" limitations would result in a "poor" (P) rating, and three or more "poor" ratings would result in an "unsuitable" (U) rating.

"Good" soils are suitable for growing switchgrass without any modifications. "Fair" soils have at least one limitation that must be overcome before the land is suitable for growing switchgrass. "Poor" soils have too many or too severe natural limitations to be suitable for switchgrass production. It is unlikely that "unsuitable" soils would ever be suitable for growing switchgrass. The decision to overcome any particular limitation may be influenced by the financial implications of such a decision. Given the right economic conditions, "poor", or even "unsuitable" areas, may be modified to enable switchgrass production. Once the polygons were rated according to the suitability criteria, the data were imported into ArcView (Version 2) where they were mapped. Maps were produced illustrating the "good", "fair", "poor", and "unsuitable" soil areas for switchgrass.

2.2.2 Study 2: Field Crop Statistics

Based on current switchgrass production costs and yields, as well as energy prices, the maximum acceptable land cost was determined to be $60/a or $15/t. This requirement effectively excluded all of southern Ontario including, Oxford County, as well as Waterloo County. Land in the Metropolitan Toronto area, and Durham, York, Hamilton and Peel Counties was also excluded because of high land values. In some cases, short-term rents are low, but this phenomenon is largely due to developers' preference for keeping land in agricultural production until the time the property is developed in order to avoid paying property taxes. High land rents in Huron and Perth Counties ($100-200/a) are prohibitive for switchgrass production. However, given the large agricultural land base in these counties, data from parts of western Ontario are included in the study for comparative purposes. The study also excluded any region with fewer than 2500 Corn Heat Units (the areas north of, and including, Muskoka and Haliburton Counties, and northwestern Ontario) because switchgrass is not well adapted to cooler climatic regions.

The most recent survey on land rental rates for Ontario was conducted in 1991 (OMAF, 1992). The Ontario Ministry of Agriculture and Rural Affairs (OMAFRA) no longer records data on land rents, so on the advice of OMAFRA personnel and crop insurance specialists, REAP collected informal, primary data from Farm Credit Corporation specialists, with supplementary information from farmers and farm input suppliers. It was hypothesized that within a region, similar quality land would have similar rental rates. The reader should employ caution when using the averages, given the large variability observed across regions, between crops and soil types and the type of rental agreement. The 1991 OMAF data was used to estimate relative rental rates between crop land types and between regions for comparative purposes.

It was assumed that the most likely land to be converted to switchgrass production was land recently in oats, barley or hay production. These crops are generally grown on lower value land. However, the current low returns on corn, and in some cases soybean, mean a greater land area may be available for conversion to switchgrass. It was estimated that 10% of annual crops and 30% of hay land could be converted to biofuel production without significantly impacting existing land and commodity values. Crop production statistics were obtained from the Ontario Ministry of Agriculture, Food and Rural Affairs.

2.2.3 Method 3: Potential pellet plant locations

The third approach involved identifying suitable regions that would support enough switchgrass production within relatively close proximity to supply feedstock to a dedicated pellet plant with a 50,000-100,000 tonne capacity. The study was based on the information collected by methods 1&2, plus additional information obtained from land tours, site visits, soil maps and local knowledge from farm leaders.

2.3 RESULTS

2.3.1 Soil suitability matrix

Table 2.1: Soil Suitability Matrix for Switchgrass

	Degree of Suitability			
	GOOD	FAIR	POOR	UNSUITABLE
Coarse Fragment	<10% by volume	10-30%	31-65%	>65%
Slope	<4%-15%	16-30%	31-60%	>60%
Rooting Depth	>75 cm	20-75 cm	<20 cm	
Drainage	Moderately Well Rapid Well Drained	Excessive Imperfect	Poor	Very Poor
Texture	CobSL FineSL SL VFineSL GravSL GravL L SilL GravSiL SiL LFineS FineL VeryL LVeryFineS GravFineL LFineS LS SCL	CoarseS FineS VeryFineSiCL CobGravL GravCL VeryFineS SC S CobL GravSiC CL SiCL SiC VGravSL GravLS GravS VeryS CS C	HeavyC VeryGravLS VeryGravS	Peat

Note: Cob = cobbly; S= sand; L= loam; Grav = gravelly; Si = Silt; C = clay

2.3.2 Soil suitability map

The soil suitability map for eastern Ontario shows that a substantial amount of land in the region is rated "good" or "fair" (Figure 2.1). The region contains a significant area of land rated "good" and encompasses the region surrounding the town of Berwick where a switchgrass stand of about five hectares was established in 1996. At least 50% of the polygons rated as "organic" are forested areas.

Sections of eastern Ontario were assessed visually to validate the results from the GIS maps and to more accurately identify where marginal land for cash crops is located. According to REAP's rating, "good" land for switchgrass production has, among other things, a "moderately well" to "well drained" drainage rating, as well as a loam soil texture in connection with gravel, sand or silt. Some of these soils are excellent for corn and soybeans, but others may be moisture deficient during the growing season. Switchgrass is more adapted to withstand arid conditions due to its extensive root system and C_4 metabolism. Moisture-limited soils for cash crops were easily identifiable in 2001 as most parts of Ontario experienced at least one month of drought. Switchgrass could be a good alternative to conventional cash crops on farmland with rapid and excessively drained soils.

In addition to the soil suitability information provided by the GIS maps, our visual rating of the region suggests that crop rotation could be a good indicator of the suitability of land for switchgrass production. For example, the best agricultural land in eastern Ontario usually supports a corn-soybean rotation. As land quality decreases, small grains (wheat, barley) and hay appear in the rotation. Lands supporting the latter crops would be more readily available due to their lower opportunity cost. Switchgrass is well adapted to more marginal soils and crop yields would remain high (Girouard et al. 1999a,b). The use of GIS maps combined with cropping information would enable better targeting of specific counties or towns that could potentially supply a switchgrass pellet mill.

By definition, clay soil particles are small, leading to reduced porosity and fair to poor drainage. In the rating scheme used for this study, clay rated "fair", while heavy clay and poor drainage both rated "poor". An analysis of the polygons' rating revealed that some of the polygons that rated "poor" were the result of heavy clay and/or poor drainage. Others were the result of three soil factors rating "fair" (three "fair" ratings leads to a polygon rating of "poor"). It is probable that not all the areas rated "poor" on the map are truly poor. For example, in research trials near Alfred, Ontario, the average yield of seven switchgrass varieties between 1998 and 2000 was consistently higher on a clay soil compared to a sandy loam. Other switchgrass plantations in Renfrew County are also planted on soils rated "poor" for switchgrass production and appear to be performing well. In the future, the standard methodology followed to rate soils for switchgrass production will have to be revised to address the suitability of these borderline soils.

Figure 2.1 SOIL SUITABILITY FOR SWITCHGRASS IN EASTERN ONTARIO

2.3.3 Conclusions from the soil map

Two main conclusions can be drawn from the development of a soil map for eastern Ontario:

- Large areas of eastern Ontario have soils rated "good" for switchgrass production;

- Some land rated as "poor" for switchgrass production is currently used for cash crop production. Most of REAP's switchgrass sites are located on soils rated as "poor" which suggests that the standard methodology followed in this study to evaluate these soils may be conservative. This issue needs further investigation.

Recommendations for further work:

1. To incorporate current land use (forests, cities, roads) and possibly climatic data (e.g. heat units) into the current maps;
2. To perform the mapping procedure on a county basis, to increase the precision of the maps. Using the newly released version of the mapping software, the number of hectares of each soil type could be estimated;
3. To develop a methodology that would better differentiate between soils rated "poor" for switchgrass production, but based on current field experience, are probably "fair" to "good"

2.4 Results (Study 2)

Eastern Ontario has about 488,000 ha of agricultural land under primary cash crops of which an estimated 100,000 ha could be converted to switchgrass production (Table 2.2). Current oat, barley and mixed grain production would supply less than 3% of this land area. Conversion of 30% of the existing hay land accounts for more than 75,000 ha or 75% of the potential production area. Land under grain corn, silage corn and soybeans would contribute approximately 20, 000 ha. Based on an average yield of 9 t/ha (tonnes dry matter), eastern Ontario has the capacity to produce about 900,000 tonnes of switchgrass biomass.

The estimated land area available in central Ontario is about 50% lower than in eastern Ontario (Table 2.2). Approximately the same proportions of the major cash crops would be converted to switchgrass production as in eastern Ontario. By contrast, the total available land area in western Ontario is about equal to that of eastern and central Ontario combined. Proportionally more land would need to be converted from land currently under corn and soybeans (33%) and somewhat less (59%) would be obtained from existing hay land. Less than 10% would be derived from small grain cereal production.

The potential land area for switchgrass production is fairly evenly distributed throughout eastern Ontario (Table 2.3). Stormont, Dundas and Glengarry Counties combined have almost 22,000 ha whereas Renfrew, Prescott & Russell and Ottawa-Carleton each support about 14,000 ha. Ottawa-Carleton probably has somewhat less potential than other counties due to

Table 2.2 Potential land base for switchgrass production and biomass tonnage in Ontario by region												
Region	**Eastern**				**Central**				**Western**			
Crop	Total Land Area (ha)	Land Area (%)	Land for Biofuel (ha)	Yield (tonnes)	Total Land Area (ha)	Land Area (%)	Land for Biofuel (ha)	Yield (tonnes)	Total Land Area (ha)	Land Area (%)	Land for Biofuel (ha)	Yield (tonnes)
Oats	7,368	10	737	6,633	4,676	10	468	4,212	7,692	10	769	6,921
Barley	21,093	10	2,109	18,981	9,109	10	911	8,199	59,312	10	5,931	53,379
Mixed	6,518	10	652	5,868	8,907	10	891	8,019	45,547	10	4,555	40,995
Corn	28,340	10	2,834	25,506	10,324	10	1,032	9,288	45,425	10	4,543	40,887
Corn	95,749	10	9,575	86,175	29,960	10	2,996	26,964	193,319	10	19,332	173,988
Soya	74,089	10	7,409	66,681	53,036	10	5,304	47,736	206,478	10	20,649	185,841
Hay	255,061	30	76,518	688,662	116,802	30	35,040	315,360	264,980	30	79,494	715,446
Total	*488,218*		*99,834*	*898,506*	*232,814*		*46,642*	*419,778*	*822,753*		*135,273*	*1,217,457*

Source: OMAFRA, Field Crop Statistics, 2000.

the greater development in the Capital Region. The smallest land areas are found in Frontenac, Lanark, Leed & Grenville and Lennox & Addington Counties. Renfrew and Prescott & Russell Counties probably have the greatest potential for switchgrass production due to the large available land area, the relatively concentrated production zones and the relatively large areas dedicated to producing hay.

Table 2.3. Available land area and estimated production by county in Ontario

County	Available Land (ha)	Estimated Production (tonnes)
Bruce	24,701	222,309
Dufferin	7,174	64,566
Grey	21,397	192,573
Huron	23,923	215,307
Perth	19,057	171,513
Simcoe	19,972	179,748
Wellington	19,028	171,252
Western Ontario		
Hastings	9,380	84,420
Northumberland	9,927	89,343
Peterborough	9,094	81,846
Prince Edward	5,164	46,476
Victoria	11,466	103,194
Central Ontario		
Frontenac	7,413	66,717
Lanark	8,672	78,048
Leeds & Grenville	11,619	104,571
Lennox & Addington	8,632	77,688
Ottawa-Carleton	14,710	127,530
Prescott & Russell	14,154	127,386
Renfrew	13,656	122,904
Stormont, Dundas & Glengarry	21,802	196,218
Eastern Ontario		

Source: OMAFRA, Field Crop Statistics, 2000

The land areas were calculated under the assumption that the poorest land under each cash crop could be converted to switchgrass. However, additional analysis of regional land rents can further help identify areas with modest land costs. For example, 1991 data for eastern Ontario shows that corn and soybean land rented for an average of $23.57 per acre compared to $20.55 for land in barley and wheat and $13.28 for hay land (Table 2.4). Assuming the average 2001 rental cost for corn and soybean land was $70 per acre, the corresponding rents for small grain and hay land (based on the 1991 cost spread) are $61.65 and $39.84, respectively. It is evident that land costs in eastern Ontario are largely below the $60.00 per acre threshold for economic switchgrass production. Land presently suited for oats, barley and hay is the most likely to be converted to biofuel crops.

Table 2.4. Relative land rents for major field crops in Ontario in 1991 and 2001.

	Eastern		Southwest		Toronto		Ontario	
	$/acre ' 9	$/acre 01	$/acre ' 9	$/acre 01	$/acre ' 91	$/acre 01	$/acre ' 91	$/acre 01
Corn/Soya	$23.57	$70.00	$60.52	$150.00	$28.27	$125.00	$45.79	$115.00
Oats/Barley	$20.55	$61.65	$27.70	$69.20	$22.86	$101.00	$22.62	$58.81
Hay	$13.28	$39.84	$25.72	$64.30	$14.12	$62.41	$15.65	$42.25

Source: OMAF, 1991.

A more detailed picture of land values by county and regions was obtained by surveying agriculturalists. For example, good quality land in the Lancaster, Embrun, Winchester and Finch regions of eastern Ontario commonly rents for $80-110 per acre ($198-272 per ha). Similarly, land in the vicinity of Carleton Place, Almonte, and Pakenham currently rents for over $80 per acre ($198 per ha). In these areas land costs may be too high to support a switchgrass industry.

On the other hand, land in Prescott & Russell County, the Hawkesbury area, Lennox & Addington, Leeds, the Elgin area, and Renfrew County rents for between $15-40 per acre ($37-99 per ha) , well within economic limits of switchgrass production. Large tracts of land in the Lanark highlands are currently not being farmed and rental rates are negligable. Good land in the Lindsay area rents for between $50-60 per acre ($123-148 per ha) with values decreasing east of Peterborough and in the Hastings/Cambellford area. Other factors such as small field size may discriminate against regions such as Hastings/Cambellford.

Central Ontario, Hastings, Northumberland, Peterborough, and Victoria counties each have between 9,000 and 11,500 ha of land available for conversion. Prince Edward county, on the other hand, has only 5000 ha. It is important to note, however, that a region's suitability for producing fibre crops may depend as much on having a concentrated production area as on the total available land area because transportation costs (to a processing plant) need to be factored in the economic equation. Despite its small size, Prince Edward County may be a feasible area for locating a switchgrass pellet plant because of a relatively concentrated production area (see Section 2.5). Land rents tend to be somewhat higher in central Ontario depending on the proximity to urban development. Richard Hays, Chief Appraiser for eastern Canada with the Farm Credit Corporation predicts that low commodity prices could force land rents downwards in the short and medium term (personal communication).

The production area in western Ontario is evenly distributed between most counties with the exception of Dufferin County. Land rents range from $80-200 per acre. The large land base, however, suggests that some additional land could be converted to switchgrass energy crops, especially if the spread between land rents and energy prices increases.

Two regions not included in the study area due to climatic factors are the Verner district near Sturgeon Falls and northwest Ontario between Thunder Bay and Dryden. However, there is some interest in switchgrass production in the Verner district (Nipissing County) due to the low land rents ($20 per acre) and low hay prices ($66/tonne). The region was not included in the study because it receives less than 2500 CHU. However, alfalfa and corn are grown in the region and district agricultural representatives from the region believe switchgrass could be grown successfully (Andre LeMay, OMAFRA, personnel communication). Nipissing County has a total agricultural land base of about 10,000 acres.

The Thunder Bay - Dryden region is of interest due to low land rents and a lack of agricultural opportunities with conventional crops. Gordon Scheifele at Lakehead University established switchgrass test acreages near Dryden in 2001. Given that wild switchgrass ecotypes are adapted to regions ranging from the central north American plains to Labrador, there is considerable potential for switchgrass in northern regions if the present trend towards climatic warming continues.

Hay prices provide an additional indicator of the relative land values for switchgrass production because both hay and switchgrass are perennial forage crops and relatively long-lived. Hay prices tend to vary across the province. The lowest hay prices are in northern Ontario followed by central and eastern Ontario (Section 3, Figure 3.5). The highest hay prices are found in southern Ontario, primarily due to the proximity of markets for horse hay and higher land costs. Eastern Ontario has a similar land area in hay production as western Ontario (Table 2.2), yet hay prices are lower. Land rents, however are considerably lower due to lower yields, smaller field sizes and a less favourable climate for corn and soybean production. The combination of low hay prices and lower land costs make eastern Ontario an excellent location for a switchgrass pellet industry.

2.5 Results (Study 3)

Switchgrass has an advantage in some areas too cold for corn and soybeans because the crop has reasonably good frost tolerance. Areas in the 2500 CHU range with well drained soils are ideal. Five regions in eastern Ontario were identified that have good potential to locate a large-scale switchgrass pellet plant: (a) Prescott County and the Alfred area, (b) Renfrew County ranging from Arnprior to Pembroke (c) Lanark County and the Lanark Highlands, (d) Peterborough County ranging to Lindsey and Hastings, and (e) Prince Edward County. These areas were identified on the basis of suitable soil type, acceptable climate, low land costs and land availability and the availability of existing pelleting infrastructure. It is generally assumed that a newly constructed, dedicated pellet plant requires an annual processing capacity of 50,000 to 100,000 tonnes to be economically viable (Mark Drisdelle, Dell-Point Technologies, personal communication).

Prescott & Russell County

Prescott & Russell County has several advantages for switchgrass production. The region's dairy industry is in decline and large acreages are in hay production, particularly between Hawkesbury and Rockland. Although silage corn is still prominent, the land area devoted to this crop will undoubtedly decrease as dairy herd numbers dwindle. Land rents are largely in the $35 per acre range with the exception of some sections near Embrun. Field sizes are generally large. Two soil types predominate in the region: a sandy loam in the Gleyed Podzol soil group belonging to the St.Thomas Association and an Orthic Humic Gleysol clay belonging to the Bearbrook Association. Repeated cash cropping has reduced the organic matter content of the sandy loam and the soil's poor moisture holding ability supports only moderate yields of most crops. The clay soil is subject to poor spring drainage and mid-summer drought. Research trials by REAP-Canada have shown both soils to be suitable for switchgrass production. Some caution is warranted with clay soils because spring harvesting (the current recommended practice) switchgrass could be delayed by poor field trafficability. Total potential switchgrass production in the county is estimated at 127,000 tonnes (Table 2.2).

Renfrew County

The Arnprior and Renfrew area stretching towards Pembroke has the advantage of low land costs ($35-50 per acre), a large, underutilized agricultural land base and the existence of a functional pellet mill. A variety of Class 2,3 and 4 soil types are predominantly well drained and suited to switchgrass production. An alfalfa pellet mill formerly operated by Alberta Dehydrators and now owned by Ottawa Valley Grain Products is situated near Renfrew. It is currently equipped to process wood pellets and forage crops. With minimal upgrading switchgrass could be processed. In season, this plant once processed 4500 acres (1800 ha) of alfalfa. There are currently over 100 acres of switchgrass planted in the region under contract to IOGEN Corporation, (Lgoucester, Ont.).Approximately 123,000 tonnes could be produced in the region from a land area of 33,730 acres (13, 656 ha).

Lanark County

The Lanark Highlands east of Carleton Place (Perth/Lanark/Hopetown/Fallbrook) have considerable potential as a switchgrass production area. The estimated 21,000 acre (8,672 ha) land base in the county is modest, but a lack of other agricultural activity suggests that considerably more than 10% of cereal cropland and 30% of hay land is available for conversion. Land rents range from $0-40 per acre. One disadvantage is a lack of infrastructure for performing field work. A considerable amount of land is being abandoned. Although poor infrastructure is a disincentive for many family-sized farming operations, it need not be a barrier to establishing a centralized processing plant and feedstock supply presuming capital is more easily accessible.

Peterborough County

Marginal soils and modest land costs make the Peterborough area suitable for large scale switchgrass production. Land rents range from $25-40 per acre, with better land costing up to $60 per acre in the Lindsay area. The nearby Hastings/Cambellford area is also a potential production area, although it has the disadvantage of small field sizes. The total estimated production for Peterborough County is about 81,000 tonnes. Additional production could possibly be obtained from neighbouring Hastings and Victoria counties.

Prince Edward County

Prince Edward county is home to declining dairy, fruit and vegetable industries. Low quality hay can be obtained for $40/ton. Land costs approximately $30 per acre. Several larger farmers in the county are expanding, however, and competition for crop land may increase. The shallow, droughty soils are well suited for switchgrass. The county's concentrated production are will minimize transport costs to a central plant. The estimated switchgrass production potential of 46,000 tonnes (Table 2.3) would be sufficient to supply a moderate sized plant if an economic analysis proved it could be economically viable.

2.6 Conclusion

Eastern Ontario has large areas of agricultural and forest land which are predominantly lighter soils but including some clay, that are rated "good" for switchgrass production. The eastern region of the province appears to be the better suited to switchgrass production than central or western Ontario because land rents are lower and there is a relatively large, underutilized production area. About 100,000 ha (247,000 acres) of existing land could be converted to switchgrass in eastern Ontario compared to 47,000 ha (116,000 acres) and 135,000 ha (333,500 acres) in central and western Ontario, respectively. Land currently under oats, barley and hay are best suited for switchgrass production. The Lanark Highlands, Prescott and Russell County, Peterborough County, Renfrew County and Prince Edward County have the potential to supply feedstock to dedicated pellet plants with a capacity between 50,000 and 100,000 tonnes. If energy prices increase more quickly relative to land prices, then switchgrass production could be feasible on higher value land. If the current climatic warming trend continues, switchgrass production could become viable in more northerly regions.

III. Pellet fuel market assessment

3.1 Introduction

The sharp increase in global oil prices, continental natural gas and propane prices and some regional electricity prices during 2000-2001 demonstrated consumer vulnerability to fluctuations in price and supply. Farmers are looking to control energy costs and diversify their income away from conventional commodity crops. Consumers are seeking stable and inexpensive heating options. Interest in biofuels such as wood fibre, ethanol, biodiesel, straw and, more recently, fibre crops such as switchgrass, is growing. The recent ratification of a modified version of the 1997 Kyoto Protocol, the first international binding treaty to mitigate global warming by reducing greenhouse gas (GHG) emissions, has raised the stakes in developing clean burning energy sources.

Alternate energies are an emerging market in Ontario and the rest of Canada, and unique opportunities exist for biofuel pellet production. Close coupled gasifier combustion of pelletized switchgrass incorporates a novel fuel type and a technologically advanced burner technology in the early stages of commercialization. The farmer survey and land base assessment suggest considerable potential for this industry in Ontario. A more complete picture of the potential for a switchgrass pellet fuel industry can be obtained from an analysis of the existing wood pellet industry in Canada, the U.S. and Europe and energy use patterns for the province of Ontario.

3.2 Methodology

Data was drawn from the farmer survey and land base assessment sections of this report. Additional information was obtained from a variety of sources including telephone interviews, site visits, interviews with farmers, pellet processors and energy experts and the scientific literature. Economic data was obtained from government, academic and industry publications and REAP research reports.

3.3 Results

3.3.1 The wood pellet industry

Densification of wood residues into pellets for space and water heating has been used in Europe since the 1970s. The pelleting process creates a clean burning, convenient and concentrated fuel from fibrous waste such as sawdust. Wood pellet heating systems are considered an essential component of European plans to reduce GHG emissions and are targeted by incentive programs in countries such as Germany, Norway and Sweden (Malisius *et al*., 2000). Sweden and, to a lesser extent, Spain and Portugal, are currently export markets for Canadian wood pellets. Mactara Forest Products, Musquodoboit, Nova Scotia, currently exports approximately 60,000 tonnes of bark pellets to industrial markets in Europe.
In North America, wood pellet stoves became available during the 1990's. The industry is concentrated primarily in the domestic heat market. There are an estimated 500,000 pellet burning stoves and furnaces in North America with wood pellet production totaling about 650,000 tonnes (PFI, 2001). Retailer stove dealers estimate the number of wood burning appliances in Ontario at 10,000.

Federal programs such as the Renewable Energy Deployment Initiative (NRC, 2000) promote biomass energy use as a GHG reduction strategy. However, further expansion of the wood heating sector is hampered by shrinking supplies of wood residues, partly due to more efficient use of the waste fraction of delivered roundwood. For example, between 1990 and 1998, the volume of surplus wood residues declined by almost 50% across Canada (Hatton, 1999), (Figure 3.1). The exception was Quebec which recorded a substantial increase in quantities of wood bark. Many pellet manufacturers believe the diminishing supply of wood residues is critical, and that further expansion of the pellet fuel industry depends on developing a sustainable, dedicated supply of feedstock (Greg Gillepsie, Shaw Resources, personal communication). Potential biomass energy sources include wood bark, crop residues or dedicated fibre crops such as switchgrass.

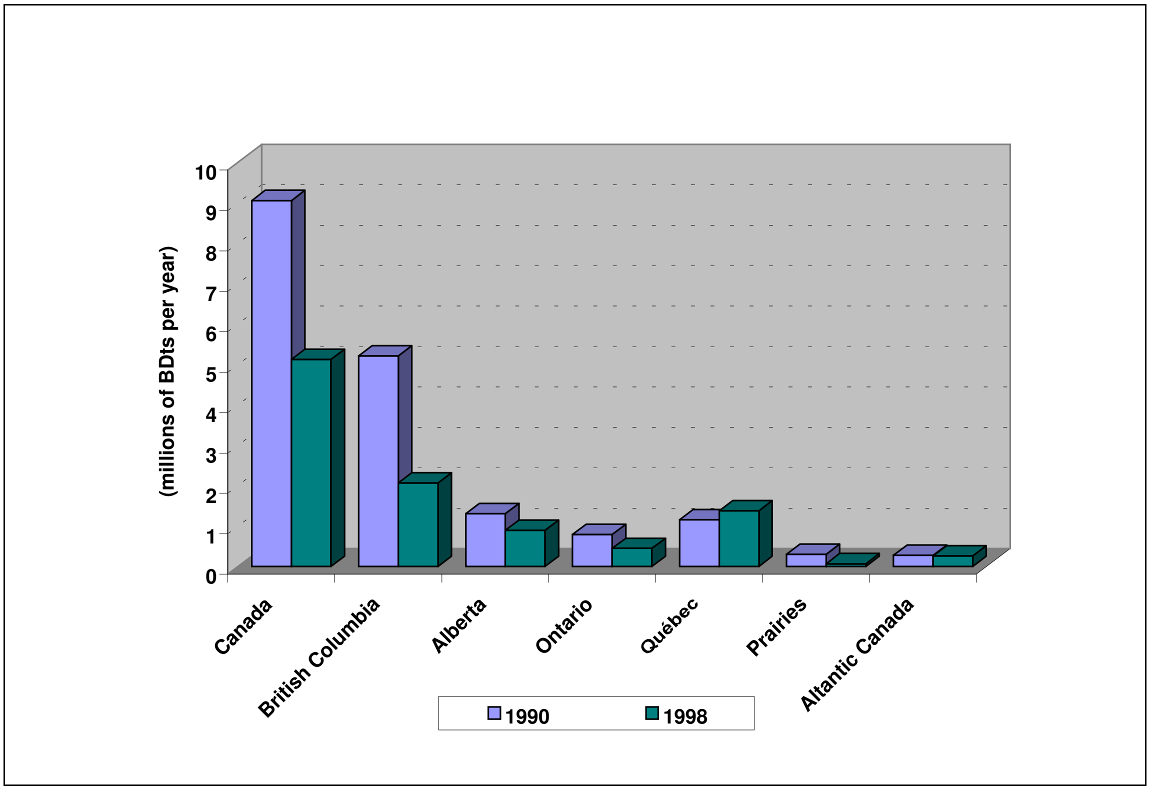


Figure 3.1 Canada's surplus wood residues (1990-1998).

3.3.2 Current pelleting infrastructure in Ontario

Pelleting infrastructure in Ontario includes wood pellet manufacturers, feed mills and alfalfa dehydrators (Table 3.1). Pelleting equipment is similar within different plants, but feedstock handling systems vary. Alfalfa dehydrators are best suited for processing switchgrass because they are equipped to handle bulk forage. Plants such as Ottawa Valley Grain Products and Les Luzernieres Belcan (QC) can process both forages and sawdust. Existing feed mills could conceivably process grass pellets provided sufficient space were available to install forage handling equipment.

The two major wood pellet processors in Ontario are Langs Dehy located in Palmerston, central Ontario, and Lakewood Industries in northwest Ontario. The Lakewood plant is located in an isolated forest region and Lang's is not equipped to handle forages. Two alfalfa dehydrating plants, Lorenz Farms and Kraehling Farms, in the Waterloo area have a combined capacity of about 8,500 tonnes. Both plants process wilted alfalfa transported in bulk from the field without prior baling. Either plant could handle switchgrass with the addition of a grinder/chopper unit for bale breaking. Strong interest has been expressed by a group of pellet mill owners, hog producers and organic farmers in the Waterloo area to establish switchgrass heating demonstration projects. High land costs, however, ($75-$150/acre) would probably limit development of a large switchgrass pellet industry in that area. On the other hand, the proximity of existing alfalfa pellet mills might enable small-scale production with limited capital investment in infrastructure.

Table 3.1 Wood and alfalfa pellet mills in Ontario

Business	Location	Product	Capacity (t)
Langs Dehy	Palmerston,	**Wood / bakery waste**	2000
Lakewood Industries	Ear Falls (N. ON)	**Wood pellets**	6000
Lorenz Farms	St. Clements	Alfalfa pellets	3500
Kraehling Farms	St. Agatha	Alfalfa pellets	5000
Ottawa Valley Grain Products	Renfrew	Alfalfa / wood	4000 (idle)
Les Luzernieres Belcan	Ste. Marthe (QC)	Alfalfa	10,000

The Ottawa Valley Grain Products (formerly Alberta Dehydrators) plant in Renfrew, Ont. is currently idle. At peak production the plant produced 4500 tonnes of alfalfa pellets from a land base of 4,500 acres. Low land costs in Renfrew County ($20-50/acre) combined with a large agricultural landbase could potentially generate enough inexpensive feedstock to supply a large, modern 100,000 tonne plant.

Les Luzernieres Belcan is an alfalfa and wood pellet mill situated in Ste. Marthe, Quebec, about 10 km east of the Ontario border. Production capacity is about 10,000 tonnes, with additional unused capacity in the winter months in periods when wood fibre is unavailable. Most of the alfalfa feedstock is transported in round or large square bales. Alfalfa is currently being imported from Ontario to Quebec for processing. The Belcan operation has experience pelleting switchgrass for REAP-Canada. Minor modifications to infrastructure may be required at some plants to ensure good pellet quality (hardness and durability), (Jannasch et al. 2001).

Several types of mobile pelleting systems are available. The Italian firm "Ecotre" manufactures a range of mobile pelleting systems for herbaceous feedstocks. For example, the

Ecotre, 200 HP pelleter will produce up to 4 tonnes of pellets per hour (44 lb/HP/h) from spruce sawdust with an electrical demand of 23 KWh/tonne. Another recent Canadian innovation is a mobile pellet system developed by VIFAM Pro-Services Inc., Montreal. The unit is equipped with a 125 HP California Pellet Mill housed in a semi-trailer. This prototype model is currently being tested and throughput is predicted at 2 tonnes per hour (Appendix 2). The majority of farmers interested in biofuel pellet production indicate a preference for on-farm pelleting to minimize transportation costs.

The pelleting infrastructure currently available in Ontario would support the early stages of a commercialization phase in regions such as Renfrew County, Glengarry County and the Waterloo area. An estimated 10,000 tonnes of pellets could be processed at the existing plants in these areas. Further industry expansion would require the construction of additional plants strategically located in regions with concentrate feedstock supplies (see Section 2). In the medium term, some production capacity could potentially be provided by mobile pelleting units.

The Pellet Fuels Institute in the United States has done some analysis of the costs of wood pelleting (Council of Great Lake Governors, 1995). From a sample business plan estimate, the overall cost of a wood pellet facility (adjusted to 1999 costs and converted to Canadian dollars) producing 7-8 tonnes per hour was estimated to be $2.1 million, while the cost of a 3-4 tonne per hour facility was $1.4 million (Samson and Duxbury, 2000). Premium Pellets, Vanderhoof, B.C., recently installed a new, state-of-the-art 88,000 tonne capacity wood pellet mill for $7 million. The cost of a new switchgrass pellet plant is expected to fall within this range, depending on specifications. If existing buildings and second hand equipment were used, the investment could be substantially lower. Ecotre systems cost between US$100,000-$250,000 depending on size and specifications (Averill Cook, Pellet Fuels Institute, personal communication)

3.3.3 The wood pellet consumer, convenience and pellet quality

According to stove dealers and pellet distributors few clear demographic trends stand out among current users of wood pellet appliances in Ontario. Before 2000, the majority of wood pellet users have lived in rural areas where natural gas was unavailable. Dealers report that recent fluctuations in fossil energy prices have attracted increasing numbers of new pellet users from urban and suburban areas where natural gas is otherwise available.

Wood pellets are burned almost exclusively in space heaters generating less than 35,000 BTU. In general, pellet heaters are installed as a secondary heat source to existing oil or electrical systems. However, these units frequently supply the bulk of a dwelling's winter heat requirement. Fuel pellets are usually purchased in 20 kg bags. The pellet industry estimates that, on average, each unit consumes 2 tonnes of pellets per year.

A study describing pellet consumers in Sweden and the New England states reveals convenience is a key factor in the pellet heat market (Vinterbaeck, 1998). New Englanders rated convenience slightly ahead of heating cost and placed considerable value on creating atmosphere, reducing the amount of wood smoke in the neighbourhood and reducing their impact on global warming (Table 3.2). Swedes, on the other hand, ranked economics first, and placed less value on convenience and creating atmosphere. They were more concerned about the issue of global warming than New Englanders. It is noteworthy that New Englanders use mainly space heaters whereas furnaces are more common in Sweden. Space heaters have a lower level of convenience (fuel loading, cleaning). The Swedish experience is that pellet furnaces offer greater convenience because pellets can be handled in bulk and fuel delivery and feeding systems are often automated (Malisius et al. 2000; Cook, 1999).

Other factors that can influence customer satisfaction are pellet dustiness, pellet handling, space for pellet storage, appliance maintenance and cleaning, variable pellet quality, and the sound from the pellet appliance (fans and auger). Dealer service, high pellet quality (hardness and consistency) and improved delivery infrastructure also rate highly. REAP-Canada has shown that pellet durability needs to be improved (to prevent dust formation) by making minor modifications to the pelleting process (Jannasch et al. 2001).

Bulk pellet delivery, and one stop pellet delivery and ash removal service being introduced in some countries such as Sweden can lead to significant cost savings and greater convenience (Cook, 1999). Vinterbaeck et al. (1998) demonstrate the importance pellets users place on environmental protection, but that additional information and education on GHG emissions and improving air quality made possible with pellet heating systems are needed. The successful development of a residential switchgrass pellet market will depend on household preferences, economic considerations and consumer attitudes.

Table 3.2 Importance of key factors when considering pellets ***(scale of 1-10)***
(Source : Vinterbaeck et al. 1998)

	New England	Sweden	Difference
Economic (heating cost)	8.0	8.3	0.3
Less smoke in neighborhood	6.1	5.6	0.5
Minimal contribution to global warming	6.4	7.0	0.6
Convenience	8.7	6.8	1.9
Creating atmosphere	6.9	2.6	4.3

3.3.4 The comparative advantage of switchgrass as an energy source

Large-scale production of warm season grasses such as switchgrass has significant potential to generate an alternative renewable biomass source to wood fibre. Switchgrass belongs to the same high yielding warm season plant group (C4 photosynthetic cycle) as corn (*Zea mays*), sorghum (*Sorghum bicolor)* and sugarcane (*Saccharum sp.)*. It is one of three dominant tallgrass species native to the North American prairie and numerous ecotypes grow wild from Mexico to Labrador. In contrast to cool season grasses such as timothy (*Phleum pratense)* and reed canary grass (*Phalaris arundinacea)*, warm season grasses are 50% more water efficient and respond well to high temperatures. These are desirable qualities if the planet continues warming. In addition, efficient water use improves the combustion quality of biomass fuel because ash levels are usually low (Samson and Mehdi, 1998). In cool regions, more chilling tolerant warm season grasses such as prairie sandreed (*Calamovilfa longifolia*) and prairie cordgrass (*Spartina pectinata)* may be more productive energy crops.

The comparative advantage of switchgrass as a pelleted biofuel stems from technical, economic and environmental factors. These include:

- Switchgrass is adapted to marginal soils typified by drought and low fertility, which generally do not support cash crops such as corn and soybean.

- Switchgrass stands have a lifespan of at least 6-10 years and fossil fuel inputs are largely limited to field operations necessary for establishment and harvesting operations. The net energy output to input ratio, including processing and transportation costs, is 14.6:1, assuming a feedstock energy content of 18.5 GJ/t (Girouard *et al*., 1999a; Samson *et al*., 2000).

- Pelleting is a relatively simple and inexpensive means for upgrading energy quality. About 88 % of the original biomass energy is recovered in a final usable form after processing versus 25.5, 30.9 and 15.7% for switchgrass co-fired with coal, cellulosic ethanol from switchgrass and grain corn ethanol, respectively (Samson *et al.,* 2000).

- Using "close-coupled gasification" technology, switchgrass fuel pellets can be burned at the same conversion efficiency as in modern oil furnaces (80-85%). Each GJ of grass pellet energy delivered to consumers thus directly substitutes for one GJ of delivered oil and can be utilized without significant air pollution. Switchgrass pellets have a CO_2 loading value of 8.17 kg CO_2/GJ (Samson et al. 2000) compared to 62.13, 89.67 and 58.32 kg CO_2/GJ for natural gas, heating oil and electricity, respectively (NRC, 2001).

- Biomass, a low grade heat source, is used to displace high grade heat forms such as oil, gas and electricity for space and water heating, effectively adding value to the biomass and freeing energy for transportation and electrical applications.

3.3.5 The long-term cost outlook for grass biofuel pellets

Perennial grass crops have an advantage over fossil energy sources in that feedstock costs should follow long-term agricultural commodity prices. North American hay, corn and wheat prices have remained relatively stable over the past 20 years (Figure3.2). Hay shares many of the same production characteristics as switchgrass, and therefore provides a shadow price for switchgrass feedstock. The trend of stagnant hay prices bodes well for keeping the long-term cost of grass biofuels low and stable.

In contrast to agricultural commodities, considerably more price volatility has been evident in energy markets, particularly in 2000-2001. Oil prices increased from $13 to $33 per barrel within a 12 month period before falling back to $22 per barrel in less than 6 months. Costs for residential electricity and heating oil increased by over 25% between 1995 and 2000. (Fig. 3.3). Natural gas spot prices more than doubled in the same period before dropping to 20% of the peak price during 2001.

It is unlikely that the price for switchgrass feedstock will fluctuate to the same extent because production costs are low (Girouard et al. 1999a,b). Switchgrass production requires modest inputs of fossil fuels because solar energy is the primary input. Although prices for perennial grass feedstocks can be expected to increase in the future, it is unlikely they will rise at the same rate as fossil fuels. Perennial grass biofuels are an attractive option for the farmers and consumers identified in the survey portion of this study who are looking for stable energy options to order to better predict heating costs and increase self-reliance.

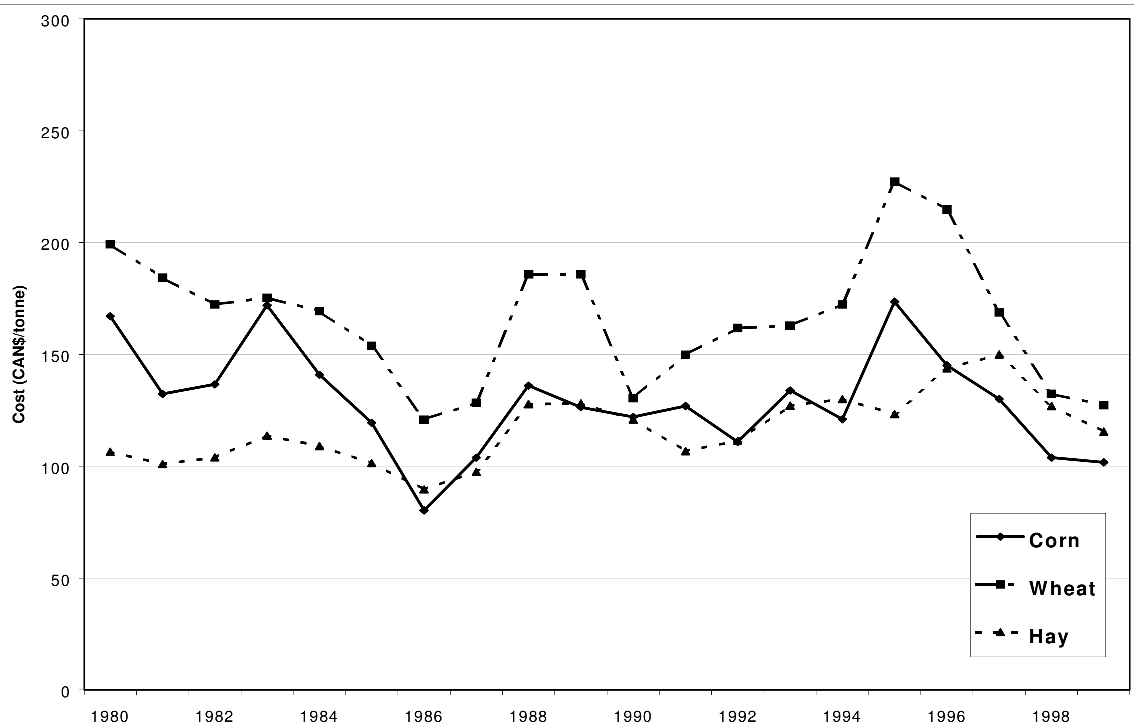


Figure 3.2 Long-term prices of corn, wheat and hay in North America (source USDA)

Hay prices vary between provinces and states (Fig. 3.4) and within the province of Ontario (Fig. 3.5). A modest upward trend is evident in most parts of North America (prices not adjusted for inflation). The exception is Manitoba where hay prices have stayed flat. Manitoba is therefore an excellent region for locating a switchgrass pellet industry. It has the disadvantage of being a long distance from major markets and producing lower per hectare yields than Ontario.

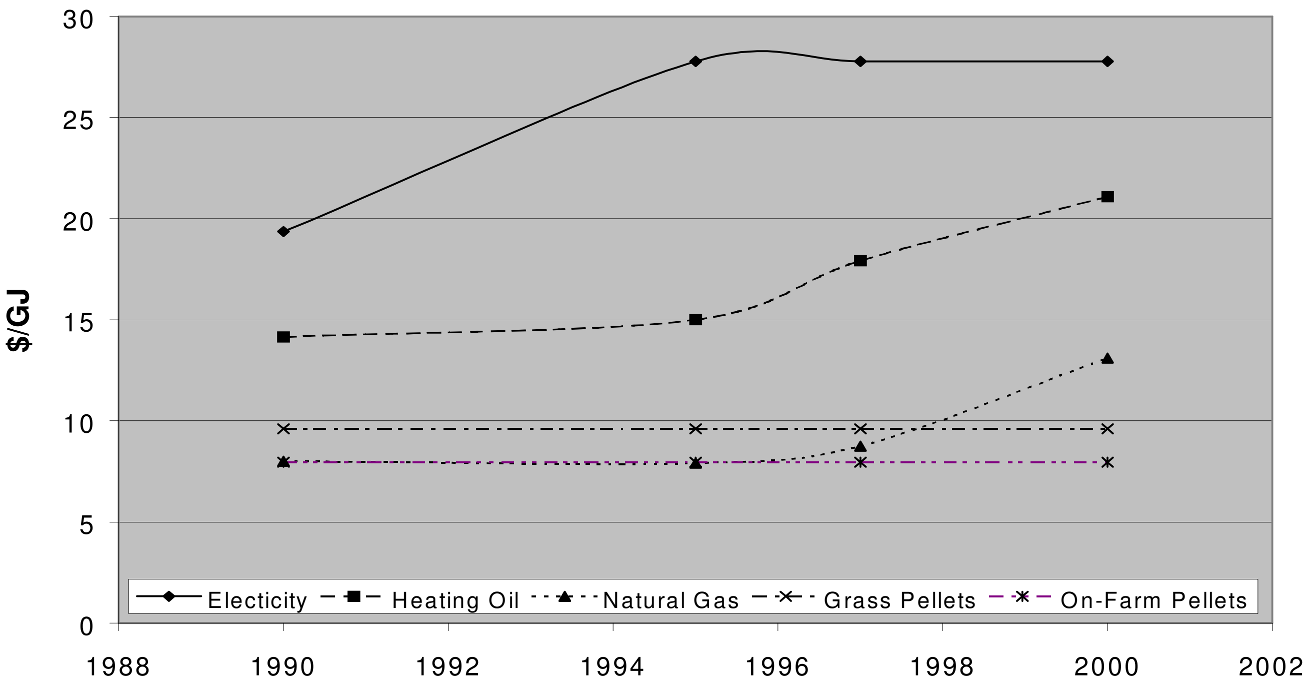


Figure 3.3 Residential energy costs in Ontario ($/GJ), 1990-2000 (efficiency adjusted).

Within Ontario, hay prices are highest in southern and western Ontario where land values are the greatest. Large scale switchgrass production is more suited to eastern and central Ontario where land rents are lower (see Section 2) The large agricultural landbase in western Ontario, however, suggests that switchgrass production may become viable should the spread between agricultural commodity prices and energy prices
increase.

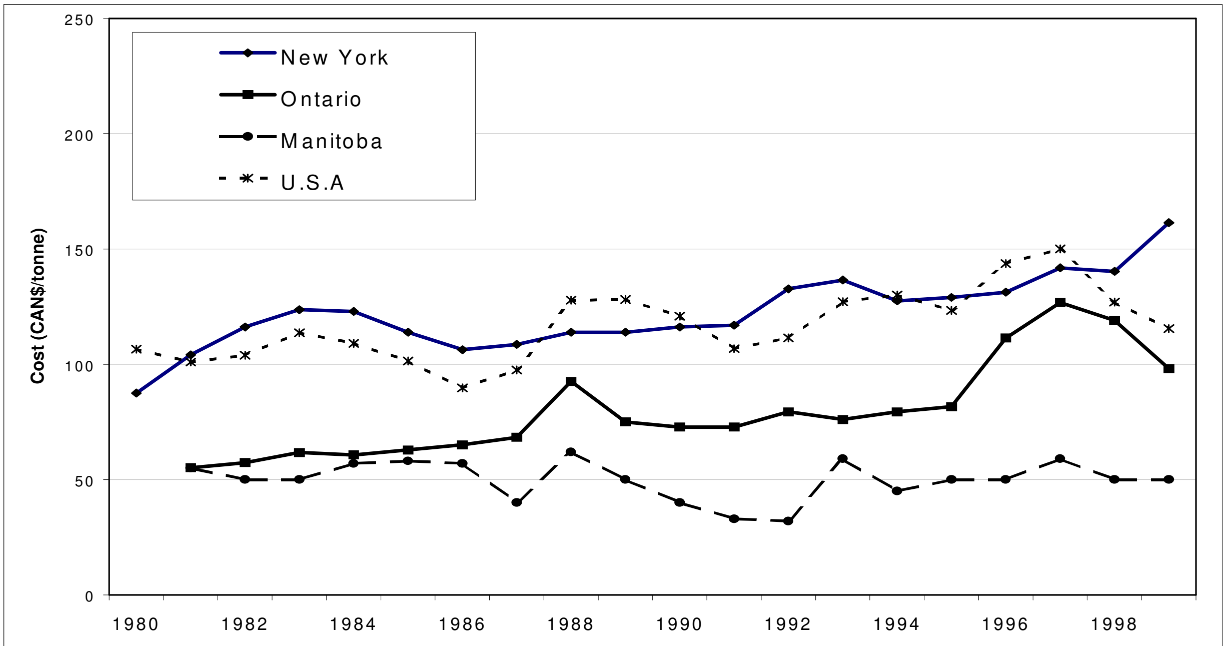


Figure 3.4 Hay Prices in Selected States and Provinces

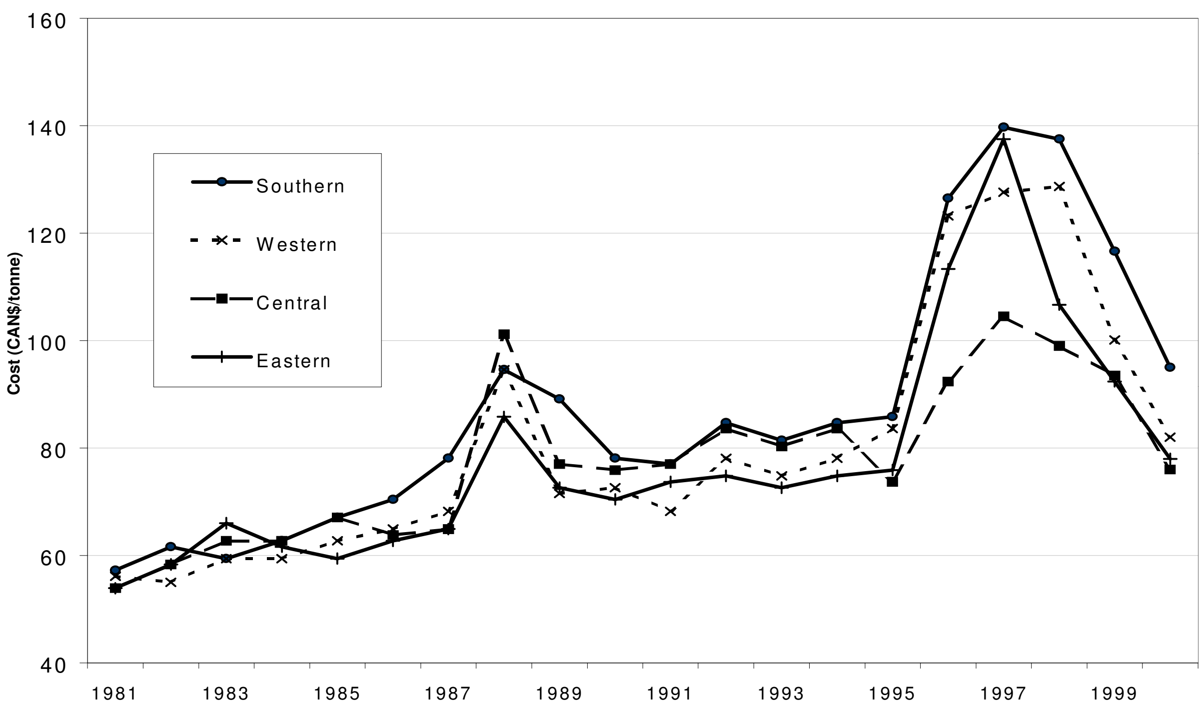


Figure 3.5 Long-term Average Hay Price in Four Regions of Ontario

3.3.6 Closed coupled gasifier combustion systems

Until recently, the use of moderate high ash feedstocks such as grasses and wood bark for manufacturing fuel pellets was limited by a lack of efficient combustion technologies capable of preventing clinker formation (fused ash residues) in the burner (King, 1999). A Quebec company, Dell-Point Technologies (www.pelletstove.com) has taken leadership in the development of close coupled gasification technology to overcome this problem. The combustion efficiency of the Dell-Point space heater is in the 80-85% range, which is comparable to modern oil burners. Most pellet stoves currently on the market have more modest efficiencies of 35-69% With the exception of stoves incorporating bottom feeding mechanisms such as the Harnam line, most pellets stoves are not equipped to burn higher ash fuels.

Dell-Point stoves are classified as supplemental space heaters, but the 34,000 BTU unit is capable of heating over 2,000 ft^2 of living space. The Dell-Point stove is designed to burn switchgrass pellets, wood pellets and corn. The stove (United Laboratories safety approved) is equipped with a battery pack, so it will function at peak efficiency during power outages. The retail price is $3100 CDN. To match the growing trend in Europe to convert underutilized fireplaces to use pellet fuel, Dell-Point has begun development of an insert model which will be introduced into the market in 2002-2003. A prototype pellet furnace for central heating has also been constructed.

A Prince Edward Island company, Grove Wood Heat Inc. is developing larger capacity heating systems producing 75,000 to 1 million BTU using similar technology to Dell-Point. The larger units could potentially heat up to 12 homes connected to a district heating system. Alternatively, the same unit could heat a 10-15,000 ft^2 greenhouse with an annual heat requirement supplied by biomass of 75-85% (depending on location and greenhouse design). Other commercial uses include wood kilns (1 million BTUs per 30,000 board feet), livestock barns, farm buildings and commercial and institutional structures.

The development of high output combustion units incorporating close coupled gasification technology is a significant breakthrough for the pellet heat industry. Large scale applications will substantially increase demand for pellets and encourage farmers to establish switchgrass plantations to meet their own farm energy needs. Moreover, handling larger pellet volumes will encourage the development of bulk handling systems which should help reduce fuel costs and encourage expansion of the industry.

3.3.7 Heating costs with switchgrass pellets

The cost of heating a 2000 ft^2 home with a 90 GJ heat demand (Toronto 80 GJ, Ottawa 100GJ) with a Dell-Point close coupled gasifer stove would be $1213 compared to $2234, $1664, $882 and $2302 for electricity, heating oil, natural gas and propane, respectively (Figure 3.6). Switchgrass pellets offer substantial saving over electricity, heating oil and propane and are comparable to the cost of wood pellets. It is estimated that switchgrass pellet prices could be reduced from $210 to $175 per tonne by handling bulk pellets (bagging costs range from $20-$25 per tonne). The cost of heating a home with switchgrass pellets would decrease from $1213 to $1011. *

Natural gas is the most economical fuel type in regions where it is available. Biofuel pellets are an attractive option in areas without natural gas service. Although the domestic heating market for propane is relatively small, propane is widely used in rural areas as a fuel for crop drying and heating greenhouses and livestock barns. The introduction of large capacity pellet furnaces would expand the range of application for pellet heating systems. None of the above cost analyses have assumed any level of government subsidy or industry support. Costs could be trimmed substantially were the switchgrass pellet industry to benefit from the same level of subsidy or support provided to other energy sectors.

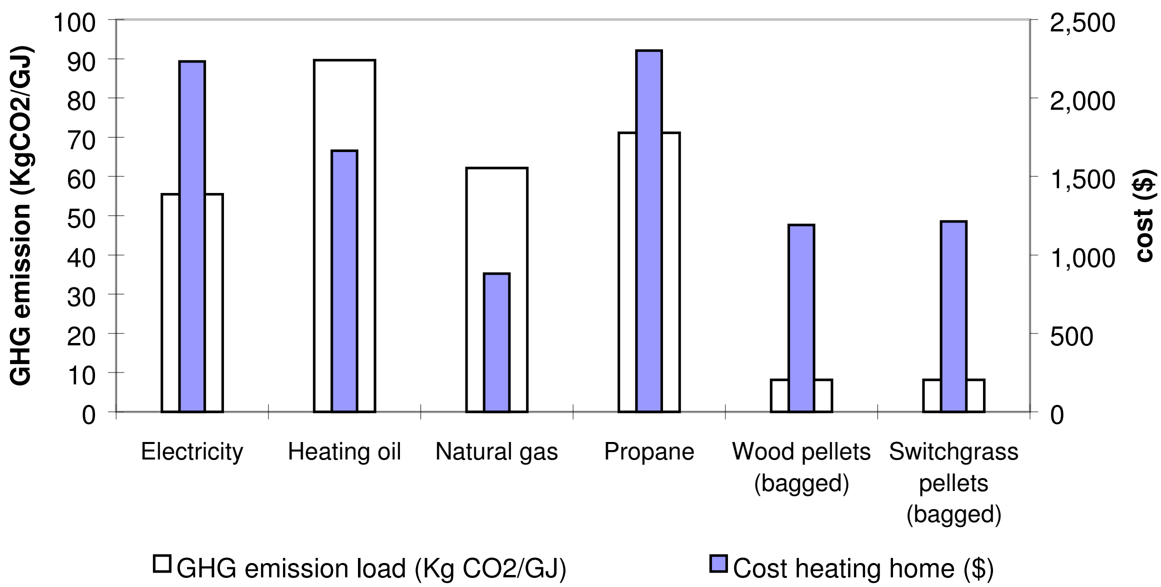


Figure 3.6 . He ating costs and C02 emissions in Ontario according to fuel types

Assumptions (see Appnedix 3.1)

Electricity has an energy content of 0.0036 GJ/kWh, a delivered fuel value of 8.93 cents/kWh, a $C0_2$ loading value of 55.46 kg $C0_2$/GJ and is converted at 100% efficiency. The approximate electrical mix for Ontario is: 27% hydro-power, 39% nuclear, 13% coal, 13% oil, 6% natural gas and 2% other (NRC, 2000).

Heating Oil has an energy content of 0.0387 GJ/l, a delivered fuel value of 58.64 cents/l, a $C0_2$ loading value of 89.67 kg $C0_2$/GJ, and is converted at 82% efficiency.

Natural Gas has an energy content of 0.03723 GJ/m^3 ,a delivered fuel value of 31 cents/ m^3, a $C0_2$ loading value of 62.13 kg $C0_2$/GJ, and is converted at an average efficiency of 85%

Propane has an energy content of 0.0253 GJ/l, a delivered fuel value of 55 cents/l, a CO_2 loading value of 71.14 kg CO_2/GJ, and is converted at an efficiency of 85%.

Wood Pellets (bagged) have an energy content of 19.8 GJ/tonne, a delivered fuel value of $215/tonne, a $C0_2$ loading value of 8.17 kg $C0_2$/GJ, and are converted at 82% efficiency

Switchgrass Pellets (bagged) have an energy content of 19.0 GJ/tonne, a delivered fuel value of $210/tonne (based on a $70/t feedstock cost, $60/t pelleting costs, $20/t transport, plus 40% retail mark-up) and a $C0_2$ loading value of 7.96 kg $C0_2$/GJ, and are converted at 82% efficiency.

[b] Heat estimates made for a new detached 2000 sq. foot home with a 90GJ heat requirement (Natural Resources Canada, 1997). The analysis does not include capital costs associated with equipment.

3.3.8. The payback period on a Dell-Point pellet stove

The payback period on a 34,000 BTU Dell-Point retailing for $3100 stove varies according to the heat demand, energy prices and the heating system replaced (heating oil, electricity or propane). For example, in areas with a 100 GJ/yr heat demand such as Ottawa, the payback period (using bagged pellets at $210 per tonne) would be 8.53, 3.16 and 2.94 years if replacing oil, electric or propane heat, respectively. At a bulk pellet price of $175 per tonne, the payback period would be reduced substantially to 5.31, 2.59 and 2.44 years, respectively. The most rapid payback would be in northern areas with a long winter heating season. The payback period for a stove in an area with a 110 GJ heat demand would be less than five years when replacing oil and about 2 years when replacing electricity or propane.

Table 3.3. Payback period for a Dell-Point pellet stove according to displaced fuel type (heating oil, electricity or propane), level of heat demand and pellet price.

	Low Heat Demand (90 GJ/yr)			Medium Heat Demand (100 GJ/yr)			High Heat Demand (110 GJ/yr)		
Pellet price	$175	$210/t	$240/t	$175	$210	$240	$175	$210	$240
Heating oil	6.04	9.89	23.98	5.31	8.53	18.79	4.73	7.51	15.61
Electricity	2.90	3.56	4.41	2.59	3.16	3.90	2.33	2.84	3.50
Propane	2.74	3.31	4.03	2.44	2.94	3.57	2.20	2.65	3.21

It is assumed that the savings over conventional energy sources will be used to finance the stove payments.

3.3.9 Reductions in carbon dioxide emissions

Switchgrass pellets burned using close coupled gasification technology produce 86-91% fewer CO_2 emissions than other major energy forms (Figure 3.6). Consequently, the system is a highly effective GHG reduction strategy. For example, every 100 ha of switchgrass converted to pellets and used to displace domestic heat derived from fossil fuels (enough heat for about 200 homes), would prevent the release of about 1800 tonnes of CO_2 annually (Table 3.4). If 100,000 ha of agricultural land in eastern Ontario were converted to switchgrass and the energy used to displace fossil fuels, CO_2 emissions would be reduced by 1.8 million tonnes.

* Energy prices have fluctuated widely over the past year and price vary between regions. The prices used in these comparisons represent best estimates compiled from farmers and energy suppliers. Actual prices may be higher or lower depending on locality and demand.

Table 3.4 . Reduction in CO_2 emissions (tonnes) per 100 ha of switchgrass used to displace heat derived from fossil fuels in Ontario.

Fuel Type	*Kg CO_2 Emitted per 19,000 GJ*	*CO_2 emissions (,000 tonnes) avoided by displacing fossil energy with switchgrass*
Electricity[a]	3.5 million	3.35
Heating Oil	1.7 million	1.55
Natural Gas	1.2 million	1.05
Propane	1.4 million	1.25
Switchgrass	0.155 million	

19,000 GJ is the heat equivalent of 100 ha of switchgrass yielding 10 t dry matter/ha converted to pellets.

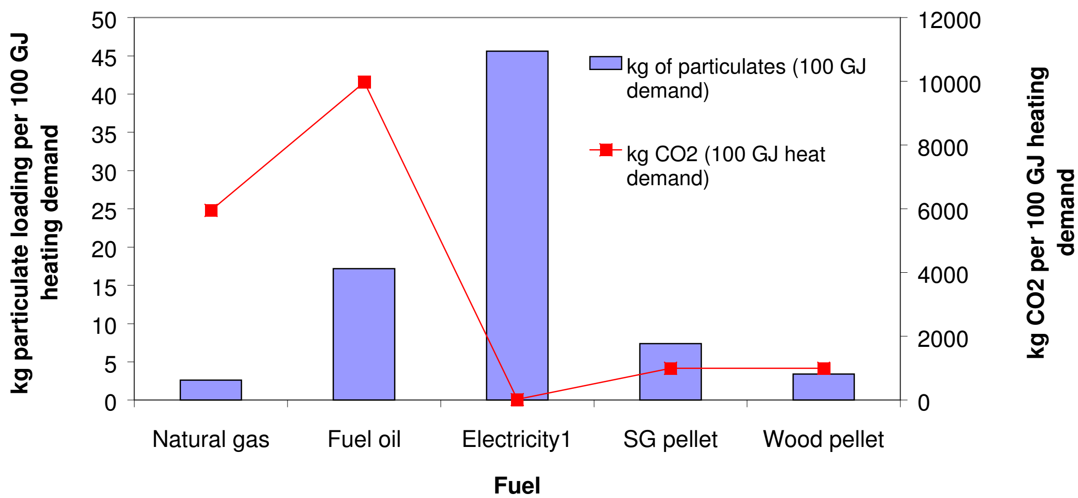
[a] Based on a marginal fuel mix for electricity generation of 50% coal and 50% natural gas.

CO_2 emissions trading is expected to play an increasing economic role in economic affairs. It is expected that industry will purchase agricultural emission reductions to offset their own emissions. Government will use emissions reductions to help meet international commitments such as the Kyoto Accord. Emission reduction credits represent a new income opportunity for agricultural producers. Duffey et al. (2001) attribute a value (and cost) of $20-50 per tonne of CO_2 as being economically justifiable and with little negligible impact on world economic development. Other estimates range as high as $100 per tonne (Morrison et al. 2001). Based on a conservative estimate of $20 per tonne of CO_2 emissions reduced, the potential revenues in eastern Ontario could exceed $36 million annually, depending where the pellets are burned.

3.3.10 Particulate emissions form pellet burning appliances

Pellet stoves release substantially less particulate matter than other wood combustion systems. For example, compared to wood burning fireplaces and traditional woodstoves which release 47 and 42 grams particulate per hour, respectively, wood pellet stoves release 1.2 g per hour (Samson and Duxbury, 2000). Switchgrass pellets burned in a Dell-Point stove at a high range setting produce 2.5 g/hour. The higher concentration is probably due to the greater ash content of switchgrass compared to wood. The peak value, however, is still well below the Environmental Protection Agency (EPA) limit of 7.5 grams. Although particulate emissions from switchgrass pellets are marginally higher than those of natural gas (Houck et al. 1998), carbon dioxide emissions are significantly lower (Figure 3.7).

Declining air quality due to wood smoke in communities across Canada favours the adoption of pellet burning appliances. There is increasing pressure within Canada to draft legislation limiting emissions from wood burning appliances to levels similar to those imposed by the Environmental Protection Agency in the United States. There is some indication that pellet stoves may be exempt (Jim Collins, Environment Canada, personal communication). Biofuel pellets should become increasingly attractive to consumers looking to combine the ambiance of a heater with a visible flame and a fuel which has minimal impact on the environment.



ig. 3.7. Carbon dioxide and particulate emissions from different fuel types

3.3.11 Potential for carbon sequestration by heating with switchgrass pellets

Perennial grasses have the potential to sequester carbon in terrestrial carbon sinks by virtue of continuous soil cover, reduced tillage, prolonged root growth and repeated above ground biomass production. In a two year study using 3 year old plantations, Zan *et al.* (2001) found that soil carbon accumulation under a fall switchgrass harvesting regime was dependent on soil type and fertilizer application. Under low fertilizer nitrogen levels switchgrass stands did not always function as a carbon sink. Spring harvested switchgrass, on the other hand, might increase soil carbon more rapidly due to plant leaf and tissue loss over winter. Spring harvesting is preferable for biofuel production because ash levels decline over winter. More long-term studies are needed to determine levels of carbon sequestration over the life of a mature switchgrass stand. Proven levels of sequestration would make switchgrass plantations eligible for carbon credits enabling producers to generate further revenues from the crop.

3.3.12 The economic value of replacing conventional energy sources with grass biofuels

Based on current energy markets, switchgrass fuel pellets are a cost-effective alternative to electricity, heating oil and propane. The average annual demand for these fuels in Ontario between 1990-1998 was about 79 PetaJoules (PJ) with a market value of about $1.7 billion (Table 3.5). A 100,000 ha land area planted to switchgrass in eastern Ontario would yield 17.1 PJ (9 tonne/ha @ 19 GJ/tonne) or a converted yield of 14 PJ. This amount of heat would meet 18% of the demand for electricity, oil and propane currently used for domestic space heating in the province.

The current market value of switchgrass is about $70/tonne (Girouard et al. 1999; Rick Rutley, farmer, personal communication). The potential farm gate value of switchgrass grown on 100,000 ha in eastern Ontario would be $63 million. The return to farmers for selling switchgrass fibre would be comparable to hay. The value of the same crop converted into pellets (in bulk @ $175/tonne) would be $158 million. The economic impact could be much larger if the market for water heating, as well as industrial and commercial heat applications were considered.

Table 3.5. Average annual energy demand for domestic space heating in Ontario (1990-1998)

Ontario	*Space Heating Demand ($)*				
	Average Demand (PJ)[a]	Energy Content (GJ/unit)[b]	Efficiency[b] (%)	Price ($/unit)[b]	Average Demand (000 $)[c]
Electricity	34	0.0036	100	0.0894/ KWh	843,861
Natural Gas	222	0.03723	85	0.31/m^3	2,174,717
Residential Heating Oil	39	0.03868	82	0.59/ L	721,038
Wood	24	-	-	-	-
Propane	6	0.0253	85	0.55/L	153,453
Wood pellets	0.38[d]	19.0	60	215/tonne	4,300

a,b,c see Appendix 3.2.

[d] Estimated 10,000 units (Chuck Gobiel, Renewable Energy, personal communication) with estimated 2 tonne average annual demand per unit at 19.0 GJ/tonne (Samson et al. and estimated 60 % efficiency.

3.3.13. Future energy markets in Ontario

Recent predictions indicate that domestic energy demand will increase modestly for most fuel types in Ontario over the next 15 years (Table 3.6). Short-term price fluctuations are expected to occur, especially in light of the economic and political fallout from the New York terrorist attacks. The economic downturn following the attacks has meant a drop in energy prices, but longer-term military conflict may reverse this trend. Climate change itself could produce significant changes in energy use patterns (Chiotti, 2001).

Of particular interest is the increasing use of natural gas, both as an inexpensive fuel choice and as a fuel suited to large scale GHG reductions. Robert Meneley, Chief Analyst for the Canadian Gas Potential Committee, warns, however, that existing and undiscovered gas reserves may not support accelerated use of natural gas as a fuel to reduce GHG emissions. Moreover, 'Future gas supplies will not be the low cost type that has been enjoyed up till now." (Meneley, 2001).

Table 3.6 Projected domestic energy demand (PetaJoules) in Ontario (2000-2015)

	2000	2005	2010	2015
Electricity	164.7	167.8	171.1	183.2
Natural Gas	371.5	363.8	349.9	362.5
RPP	24.3	18.7	19.8	28.9
Coal	0	0	0	0
LPG	5.7	8.5	11.2	8.6
Wood	22.2	24.6	26.9	29.6

Energy markets are expected to continue expanding in the short and medium term although volatility due to supply factors such as refining capacity, depletion of world reserves and political tensions is expected to increase. Opportunities for additional large-scale electricity generation – from hydro power or nuclear fuels- are limited due to environmental and security risks. Security of domestic energy supplies and self-reliance within Canada are expected to become increasingly important. Alternate energy sources such as biomass should become an important component of a diverse, decentralized energy supply

3.3.14 Increasing electricity exports

Strange (2001) reported that the national electric energy exports totaled 18,779 GigaWatt hours between January and May, 2001, and earned revenues of $2.8 billion. Substituting switchgrass biofuels for electricity currently used for space heating in Ontario would make an estimated 10,000 GWH of additional electricity available for export (NRC, 2001a). Meeting one percent of the domestic electric heat market would generate $15 million in revenues (based on 2001 prices). Alternatively, the energy could be used for shutting down aging nuclear plants or displacing production from high CO_2 loading coal plants. Regardless of the electricity's end use, displacing even a small portion of the Ontario's electrical heat demand with grass pellet biofuels would produce significant economic returns and help Canada meet its obligations under the Kyoto Protocol to reduce GHG emissions.

3.4 The Wood Pellet Industry in Europe

3.4.1 The European wood pellet market

Heat is the most important energy form needed in the European Union and accounts for about 50% of the European energy market. Low temperature heat from low quality heat sources such as pelletized biomass are considered essential to meeting future energy demand (Malisius et al. 2000). Leaders in the energy and climate change sectors claim that the rapid introduction of renewable energy sources is essential to meet the obligations of the Kyoto Protocol and that it will not be possible to comply without a rapid introduction of biomass into the heat market (Malisius et al. 2000).

Wood pellet production in Europe originated in the late 1970s in Sweden and has since expanded to include at least 16 countries (Table 3.7). The "Industrial Network on Wood Pellets" project sponsored by the European Commission recently concluded that despite a small share of the current energy market wood pellets have enormous potential as a biomass fuel (Malisius et al. 2000). The availability of raw material, competitive prices and diversified energy policies favour development of a wood pellet industry. Sweden, Germany and Austria have the most highly developed pellet markets. The primary use for pellets (in stoves, furnaces or industrial applications) varies between countries depending on national forestry structures, the scale of woodworking industries and heating habits. The low CO_2 loading status of biomass fuels, and the trend towards reduced dependence on nuclear power, favours the development of a biofuel pellet market in Europe.

Table 3.7 European Wood Pellet Production in 1999

Country	Number of Producers	Production (tonnes / year)
Austria	13	51,500
Bulgaria	1	300
Denmark	6	107,000
Estonia	2	60,000
Finland	5	84,000
France	3	16,000
Germany	10	30,500 *
Hungary	1	No data available
Italy	2	44,000*
Latvia	4	67,000
Netherlands	2	No data available
Norway	5	24,200 *
Spain	1	9,000
Sweden	15	766,000
Switzerland	2	3,000*
U. Kingdom	1	No data available

TOTAL	**73**	**1,262,500**

*Not all producers reporting production

Sweden

About 60% (766,000 tonnes) of European wood pellets are produced in Sweden. Total capacity is estimated at over 1,000,000 tonnes. One large-scale central heating plant consumes about 220,000 tonnes. Most of the remaining tonnage is delivered to medium-sized boilers (20-50 kW). The market for residential heating is still small. In 1998, Sweden imported 100,000 tonnes of wood pellets, mainly from Canada. The manufacturing price in Sweden is about 725 Swedish Krona ($115) per tonne.

Germany

German wood pellet production is still relatively small. However, favourable tax laws for installation of biofuel combustion systems and large quantities of available wood fibre (7 million tonnes of scrap wood from sawmills and commercial timber alone) make Germany one of the most promising pellet markets in Europe. About 30% of the country is covered in woodland. The primary use for pellet fuels is expected to be the low-energy house market. Development of the pellet market will depend on future trends in conventional energy prices and improved information and marketing campaigns. In 1999, about 1000 pellet stoves were sold in Germany (Malisius et al. 2000).

Austria

The number of houses heated with wood has been declining in Austria since the early 1990's. Total forest area, on the other hand, is increasing by 7000 ha per year. Most fuel wood is currently used in old fashioned wood boilers for space heating in single family dwellings. Log wood and wood chips are relatively inexpensive. Wood pellets are a more expensive heating option in Austria than Germany or Sweden (Table 3.8). Wood pellets are viewed as an opportunity to increase convenience and reduce emissions compared to older heating systems. Current pellet production is about 50,000 tonnes. The market is expected to increase to 100,000 tonnes by 2003 (Malisius, 2000). High investment costs for biomass and pellet furnaces have hindered market penetration, but recent innovations in automated pellet feeding and fuel delivery systems have markedly increased interest in pellet heating systems.

Table 3.8 Wood pellet and fossil energy prices in Europe in 2000 (Euro/kWh).

	Wood Pellets (Bulk)	Oil	Gas	Electricity
Sweden	0.021	0.046	*	0.084
Germany	0.036	0.060	0.035	0.112
Austria	0.041	0.048	0.049	0.152

*limited availability

Other countries

Pellet heating is expanding in other European countries such as Norway, Switzerland Holland, Italy, Spain and Portugal. At present, 50% of Norway's total energy consumption is provided by electricity (Malisius et al. 2000). About 70% of household electricity is used for heating and hot water. With off-shore oil supplies expected to decline and only limited capacity to expand hydroelectric production, competitively priced pellet fuels have good potential to displace electricity for heating applications. Despite the "critical" shortage of electricity in Norway, wood pellet production currently exceeds consumption by a large margin and a government-driven effort is needed to help establish a consumer market (Malisius et al. 2000). The major barriers to greater market penetration in Europe are non-technical (e.g. lack of information, underdeveloped infrastructure, heating traditions and economy) rather than technical barriers such as efficient processing and combustion methods.

Wood pellet technology development

Sophisticated transport systems are being developed to improve pellet quality and increase convenience. Pellet delivery systems are being modeled after the livestock feed industry using pneumatic tanker trucks. Gentle pellet loading, storage and transport systems are essential to minimize the amount of dust or fines generated during handling operations. Research continues to improve pellet durability to increase resistance to mechanical abrasion (Malisius et al. 2000). Design of more efficient pellet storage, charging and combustion systems for domestic users is on-going, in order to optimize delivery of wood pellets to residential markets. One option is the development of pneumatic ash retrieval mechanisms on pellet delivery trucks to provide a 'one stop' fuel and waste removal service.

3.4.2 Europe as an export market for Canadian biofuel pellets

The great potential to expand pellet fuel markets in Europe is reflected in the decision by major oil companies such as Statoil, Hydro Texaco and Shell to enter the biofuel market. In Sweden, Statoil supplies wood pellets directly through its network of gas stations. Shell is positioning itself to increase the proportion of revenues to be derived from wind, solar and biomass energy.

Shaw Resources, in Shubenacadie, Nova Scotia, has exported wood pellets to a number of European countries including Italy, Spain, and Portugal, as well as Austria, Germany and Sweden in 2000-2001. Sales manager, Greg Gillespie, claims wood pellets have become competitive heating fuels as carbon and sulphur taxes have "priced fossil fuels off the map." Gillespie believes the pellet market is expanding rapidly, but diminishing supplies of wood residues in Canada will curtail the opportunity to export pellets from this country. In countries where natural gas provides the major energy source for home heating (Belgium, UK, Italy, Netherlands) it may take some time for biofuel pellets to penetrate the market. However, there is growing unease over the increased reliance on natural gas from non-European countries within Europe and security of supply is becoming a strong motivator for promoting biofuel pellet production.

Accessing European markets with switchgrass pellets will depend largely on production costs. European wood pellet prices vary considerably. Prices range from GBP 130 ($298) FOB (per tonne) for bulk pellets in Great Britain, DM 420 ($315) for bagged pellets in Germany (DM 319 ($207) for bulk pellets) and CHF 250-500 ($237-$475) in Switzerland (Malisius et al. 2000). Prices for pellets used as cat litter are almost double those for fuel (Giffard, 1998). An approximate world pellet price in 1998 was GBP 70 ($150) (Giffard, 1998. Prices range between $145-$165. Competing in this price range with switchgrass pellets would require large-scale production and processing plants with sufficient economy of scale to keep the cost of finished product low. Although the European market is expanding, it is unlikely exports will be economically feasible until a domestic grass pellet industry with large production plants were established. The long-term potential for exporting grass biofuel pellets to Europe or developing countries with a shortage of fuel wood is bright.

3.5 The outlook for grass fuel pellets in Ontario

The potential for developing a switchgrass pellet industry in Ontario is substantial, but realization of this opportunity depends on a number of factors. The short-term outlook for expansion is modest due to the lack of feedstock and the limited number of pellet stoves on the market designed to efficiently burn fuels such as switchgrass. There is a three year lag period until newly planted switchgrass plantations reach maximum production. The distribution of Dell-Point stoves has been limited in Ontario as marketing efforts have focused primarily on U.S. markets. A recently announced manufacturing facility in the Rouyn-Noranda region of Quebec (La Presse, April 25, 2001) should significantly increase availability and market penetration of this product throughout Canada. The capacity of the Dell-Point stove to function with several fuel type (wood pellets, switchgrass and corn) means consumers can be assured of alternate fuel supplies during the start-up phase of the industry.

Farmers can expect similar market prices for switchgrass as for hay. Production costs range between $48-68 per tonne, including an allowance for transport to processing facilities (Girouard et al. 1999b). Several small alternate markets for switchgrass exist. For example, Berwick, Ontario, grower, Rick Rutley, receives $70 per tonne for switchgrass used as livestock bedding. Customers claim the absorption qualities are superior to cereal straw. There are some reports of limited switchgrass market for mushroom compost; however, some suppliers say the material is too course. IOGEN Corporation, Gloucester, Ontario, currently has about 200 acres of switchgrass under contract to supply biomass for its new cellulosic ethanol plant. It is not clear, however, whether the efficiency of the conversion process is such that farmers will be paid above a break-even price for their crop.

The current pellet stove market is limited primarily to "after market sales" (existing homes) as secondary heat sources in the form of space heating units. It is expected that over the next three years increased knowledge and product exposure among contractors and homeowners will expand the domestic market for stoves and pellets. In the short term, however, it is not expected that homeowners alone will create a significant demand for switchgrass pellets. For example, every 1000 pellet stoves burning, on average, 2 tonnes of switchgrass pellets per year, requires a 225 ha land area to supply the necessary feedstock. Demand could change substantially if incentive programs were established by government to promote domestic biofuel heating systems. In the medium term, market penetration of pellet space heaters would increase if more stove manufacturers incorporated close coupled combustion technology in their product line.

A significantly higher demand for switchgrass fuel pellets will be created by the introduction of larger capacity pellet furnaces. Grove Wood Heat (York, PEI) is currently testing a 1 million BTU pellet burner designed for high ash fuels in cooperation with Shaw Resources in Nova Scotia. The company expects limited quantities of commercial units with outputs of between 250,000 and 1 million BTU to be available by Spring, 2002. On-farm applications of heating systems of similar scale could greatly increase demand for switchgrass pellets.

One potential application is greenhouses. For example, 1000 ft^2 of greenhouse space (double layer inflated plastic) heated to a year round, constant temperature of 22 ° Daytime and 16 ° Nighttime in the Cornwall region requires 6770 L of #2 heating oil or 263 GJ (CREAQ, 1991). Fuel pellets burned with close coupled gasifier technology can be burned at the same efficiency as modern oil burners (82-85%). Approximately 12 tonnes of switchgrass pellets would be required to heat 1000 ft^2 (assuming that 85% of the greenhouse heat demand was met by biofuels). Heating one percent of the 86,000,000 ft^2 of greenhouse space in Ontario with switchgrass would create a demand for 10,000 tonnes of pellets. Other applications include livestock barns, farm buildings and wood drying kilns. It is estimated that the combined implementation of domestic and on-farm/commercial switchgrass pellet heating systems could generate a demand for 20,000 tonnes of switchgrass pellets annually within 5 years. In the long term, pellet markets can be expected to increase further as fossil fuel prices rise, technical innovations lead to greater combustion efficiency and improved switchgrass yields lower feedstock costs.

3.6 Recommendations for development of a switchgrass pellet industry

Various mechanisms have been proposed to help the renewable energy sector expand and compete with conventional energy sources including carbon taxes, voluntary GHG reduction targets and Production Tax Credits (Saulnier, 2001). Such programs would be of great benefit to promoting a switchgrass pellet industry. However, there is also an immediate need to increase expertise and knowledge in all aspects of switchgrass pellet production and heating. Given the greatly reduced CO_2 emissions from switchgrass pellet heating systems, it would appear that it should be an attractive option to help Canada meet its obligations under the Kyoto Protocol. This study has identified the following recommendations for developing a grass biofuel pellet industry:

- Support for large and small-scale demonstration projects at government and institutional buildings and domestic dwellings is essential. Ontario wood pellet distributor, Walter Bunda, is planning to establish a 2 ha switchgrass plantation in 2002 to assess the economics of manufacturing pellets for on-farm heating applications using a Dell-Point stove. A lifecycle energy and carbon analysis of this system is needed to demonstrate the efficacy of the system.

- Increase public awareness by showcasing the economic and environmental benefits of pellet fuel heating systems and specifically to encourage the introduction of flexible fuel pellet stoves capable of using bark, switchgrass and other moderate high ash fuels.

- Upgrade existing pelleting infrastructure in Ontario to support an industry start-up phase with emphasis on producing uniform pellets of good durability.

- Assessment of mobile pelleting systems as a possible means to increase pelleting capacity in Ontario with minimum large scale investment and offering a high degree of flexibility to farmers.

- The feedstock supply must be increased to support a larger market.

- Plant breeding and selection research for greater seedling vigour and earlier plant maturity.

3.7. Conclusion

Wood pellet heating systems are considered an essential component of Europe's alternate energy and GHG reduction strategy, but expansion of the wood pellet industry in Canada is limited by a lack of surplus wood residues. Ontario currently has the capacity to pelletize about 10,000 tonnes of alternate feedstock such as switchgrass at existing alfalfa dehydration and wood pelleting facilities. Although these plants are not ideally located, it is anticipated they would support the early commercialization stage of a grass biofuel pellet industry. The investment to construct a dedicated pellet plant with a capacity greater than 50,000 tonnes annually ranges between $2 –7 million.

It is expected that switchgrass feedstock costs will follow stagnant long-term aricultural commodity prices and therefore remain lower, and fluctuate less, than fossil fuel prices. The incorporation of close coupled gasification technology in pellet stoves produced by Dell Point Technologies enables the combustion of moderately high ash fuels such as switchgrass at efficiencies of 80-85% Similar technology being incorporated in larger capacity pellet furnaces provides the opportunity to heat a broad range of structures including domestic dwellings, farm buildings and greenhouses. It is estimated that the cost of heating a 2000 ft^2 home with switchgrass pellets using a Dell-Point 34,000 BTU space heater is $1213 compared to $2234, $1664, $882 and $2302 for electricity, heating oil, natural gas and propane, respectively.

Emissions of CO_2 would be reduced from 86-91% compared to conventional energy sources, a benefit which could generate substantial revenues for farmers by way of carbon emission credits. Switchgrass fuel pellets produced from 100,000 ha in eastern Ontario could meet 18% of the current demand for electricity, oil and propane used for domestic space heating in Ontario. The farm gate value of the crop would be $63 million whereas the value of pellets is estimated at $158 million. It is anticipated that the economics will improve as fossil fuel prices and energy consumption in Ontario rise.

The European wood pellet industry serves as a model of how rapidly a pellet industry can evolve. Widespread production, emphasis on customer convenience, government incentives and buy-in by conventional energy companies has enabled the pellet industry to develop from a novel concept to a modern and efficient energy system. Europe has good market potential for Canadian pellets in the long-term.

The potential for developing a switchgrass pellet industry in Ontario is substantial although the short-term outlook for market expansion is modest due to the lack of feedstock and the small number of pellet stoves currently in use. Increased production and market penetration of combustion units designed to burn switchgrass pellets should improve prospects over the medium term. Pellet furnaces with outputs of between 250,000 and 1 million BTUs currently being developed should greatly increase the demand for switchgrass pellets. The adoption of biofuel pellet heating systems will depend in part on energy prices and Canada's commitment to reduce greenhouse gas emissions. The combined implementation of domestic and on-farm heating systems could generate a demand for 20,000 tonnes of pellets annually within 5 years. Alternate uses for switchgrass such as livestock bedding, compost substrate and as a feedstock for ethanol production will limit risk or growers. Support and incentives for demonstration projects and public awareness programs are needed to promote the industry.

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Appendix 1

Switchgrass pellet industry survey form

Appendix 3.1

Table 1. HEATING FUEL COSTS AND GHG EMISSIONS IN ONTARIO

Fuel	Energy content[a]		Efficiency[b]	GHG emission load (Kg CO_2/GJ)[c]	Price[d]		Price	Cost heating home ($)[e]	Cost heating home ($)
Electricity	0.0036	GJ/kWh	100%	55.46	0.08935	$/kWh	0.08528	2,234	2,132
Heating oil	0.03868	GJ/litre	82%	89.67	0.5864	$/litre	0.5864	1,664	
Natural gas	0.03723	GJ/m^3	85%	62.13	0.31	$/$m^3$	0.43	882	1,223
Propane	0.0253	GJ/litre	85%	71.14	0.55	$/litre	0.55	2,302	
Wood pellets (bagged)	19.8	GJ/tonne	82%	8.17	230	$/tonne	230	1,275	
Switchgrass pellets (bagged)	19	GJ/tonne	82%	8.17	210	$/tonne	210	1,213	

Table 2. Electricity Mix in Ontario

	Energy mix[f]	GHG emissions: Kg CO_2/GJ[c]	GHG emissions: weighted Kg CO_2/GJ
hydro	27%	-	-
nuclear	39%	-	-
coal	13%	304	39.52
natural gas	6%	62	3.72
oil	13%	94	12.22
other/renewables	2%	-	-
	100%		**55.46**

Table 3. GHG Emissions from Switchgrass pellets:

	Energy use[g]		Energy sources[h]		GHG emissions[i]
	MBtu/ton	GJ/tonne	Electricity	Gasoline	Kg CO_2/GJ
switchgrass production					3.48
transportation	0.055	0.064	50%	50%	0.21
pelleting	1.068	1.240	100%	0%	3.62
sales and management	0.023	0.027	70%	30%	0.08
delivery	0.143	0.166	40%	60%	0.57
					7.96

a_ Canada' s Emissions Outlook: An update, athttp://www.nrcan.gc.ca/es/ceo/update.htm visited on July 9 2001,
Office of Energy Efficiency, http://energy-publications.nrcan.gc.ca/index_e.cfm visited on July 9 2001 and
Samson Roger, P. Duxbury, M. Drisdelle and C. Lapointe, 2000. Assessment of pelletized biofuels. Unpublished.
Montreal: REAP-Canada: www.reap.ca.

b_ Office of Energy Efficiency, http://energy-publications.nrcan.gc.ca/index_e.cfm visited on July 9 2001

c_ Canada' s Emissions Outlook: An update, athttp://www.nrcan.gc.ca/es/ceo/update.htm visited on July 9 2001
Canada' s greenhouse gas inventory, athttp://www.ec.gc.ca/pdb/ghg/ghg_docs/gh_eng.pdf visited on July 9 2001
For electricity and switchgrass see tables 1 and 2.

d_ Residential home heating cost comparison, at http://www.uniongas.com/Residential/ResCostComp/CstCmpIndex.asp
(prices in March 2001) on July 9 2001 and http://www.energyshop.com visited (prices in March, April and June 2001) on
July 9 2001. The price of propane was obtained directly surveying rural households (May-August 2001).

e_ Assumption: new detached house, 2000 f^2 , energy requirement for heating: 90 GJ/year (average for Ottawa and Toronto),
from Office of Energy Efficiency, http://energy-publications.nrcan.gc.ca/index_e.cfm visited on July 9 2001.
heating cost = [90 GJ x price ($/unit energy)] / [energy content (GJ/unit energy) x efficiency]

f_ Ontario Ministry of Energy, Science and Technology. Energy Fact Sheets. Website:
http://www.est.gov.on.ca/english/en/en_consume_fact6.html visited on August 30 2001.
Coal + oil = 26%, it was assumed this is distributed equally between coal and oil (50% each = 13%).

g_ King Joseph, 1999. Pelletized switchgrass for space and water heating. Kansas: Coriolis and Kansas Corporation Comission

h_ Adapted from King Joseph, 1999. Pelletized switchgrass for space and water heating. Kansas: Coriolis
and Kansas Corporation Comission

i_ For switchgrass production emissions were taken from Girouard Patrick, C. Zan, B. Mehdi and R. Samson, 1999. Economics and carbon offset potential of biomass fuels. Montreal: REAP-Canada

The emissions for the other parts were estimated using the following formula:

GHG emissions = [energy use (GJ/tonne) x energy source (%) x emission load (Kg/GJ from c)] / energy content (19 GJ/tonne)

Appendix 3.2

Energy Demand for Domestic space Heating in Ontario

Ontario	Space heating demand ($)				
	Average demand (PJ)a	energy content (GJ/unit)b	efficiencyb	price ($/unit)b	Average demand (000 $)c
Electricity	34	0.0036	100%	0.08935	843,861
Natural gas	222	0.03723	85%	0.31	2,174,717
Residential heating oil	39	0.03868	82%	0.5864	721,038
Wood	24				
Propane	6	0.0253	85%	0.55	153,453

a_ Natural Resources Canada, Office Energy Efficiency, http://oee1.nrcan.gc.ca/dpa/data_e/database_e.cfm visited on July 19 2001 (see spreadsheet on-qc-mb).

b_ Canada' s Emissions Outlook: An update, at http://www.nrcan.gc.ca/es/ceo/update.htm visited on July 9 2001, Office of Energy Efficiency, http://energy-publications.nrcan.gc.ca/index_e.cfm visited on July 9 2001 and Office of Energy Efficiency, http://energy-publications.nrcan.gc.ca/index_e.cfm visited on July 9 2001 Residential home heating cost comparison, http://www.uniongas.com/Residential/ResCostComp/CstCmpIndex.asp (prices in March 2001) and http://www.energyshop.com (prices in March, April and June 2001) visited on July 9 2001. The price of propane was obtained by surveying rural households (May-August 2001).

c_ The demand was calculated using the demand in PJ during the period 1990-1998 and the prices in 2001, using the following formula:

Average demand ($) = avg dem (PJ) * 1 000 000 / energy cont (GJ/unit) / efficiency * price ($/unit)

Appendix 4

Contacts and Useful addresses

Pelleting Companies

(1) Les Luzerniéres Belcan du Quebec Inc.
170, montée Ste. Marie
Ste. Marthe, Cté de Vaudreuil,
Quebec, J0P-1W0
Tel. 450-459-4546
Fax. 450-459-4366
E-mail : **ytrottier@belcan.qc.ca**

(2) Kraehling Farms Inc.
R.R.1 St. Agatha, Ontario N0B 2L0
Tel. 519-886-6276

(3) Lorenz Farms
St. Jacobs, Ontario
N0B 2N0
Tel. 519-699-5663

(4) Ottawa Valley Grain Products Inc.
Box 456
Renfrew, Ontario K7V 4A6
Tel. 613-432-6148

(5) John Swaan
President
B.C. Pellet Fuel Manufacturers Association
Box 2929, Prince George,
B.C., Canada
V2N-4T7
Email: jswaan@pellet.org

Mobile Pelleting Equipment

(1) Ecotre System
Via delle Cantoine, 12 – 50040

Settimello (FI) Italy
Tel. 39 55 8827441
Fax 39 55 8827441
E-mail : **ecotresystem@tiscalinet.it**

(2) VIFAM Pro-Services Inc.
125 Boulevard Kirkland, QC
H9J-1P1
Tel. 514-426-4482
Fax. 514-695-0408
E-mail : vifam@qc.aibn.com

Pellet stove manufacturers

(1) Dell-Point Technologies
Blainville, Quebec
877-331-6212
http://www.pelletstove.com

(2) Grove Wood Heat Inc.
York, Prince Edward Island
902-672-2090 (Vince Court)

Other useful contacts:

(1) Greg Gillespie
Shaw Resources
P.O Box 60, Shubenacadie
Nova Scotia, Canada
BON-2HO
Tel: (902) 758-4725
Hfx: (902) 883-2220
Fax: (902) 758-3662
http://www.shawresources.ca

(2) Pellet Fuels Institute
1601 N. Kent St., Suite 1001
Arlington, VA 22209
Tel: (703) 522-6778
Fax: (703) 522-0548
http://www.pelletheat.org

(3) Ottawa Wood Pellet Sales
8310 Mitch Owens Road
Walter Bunda (owner/manager)
Edward, Ontario

K0H-1V0
Tel: (613) 822-0574