The Use of Agricultural Residues and Energy Crops in Biomass Combustion Systems

Introduction

Rising fossil fuel prices and increasing concerns about climate change are creating a growing demand for new sources of raw material for biomass combustion for sustainable heat production. Agricultural sources of energy for combustion offer significant potential for increasing the quantity and controlling the rising costs of raw material. The main historic problem with the use of these materials has been that, unlike wood, they are not easy to burn over sustained periods because of their chemical properties. Recent technical innovations in biomass combustions systems combined with further understanding of strategies to improve biomass quality of herbaceous (non-woody) feedstocks are now creating the emergence of a potentially large new bioenergy sector. This factsheet provides an overview of the main opportunities and challenges and recent developments in Canada.

Historic challenges with the sector

The main barrier to the use of herbaceous biomass for heating has historically been unsuitable biomass quality for biomass combustion systems. Potassium and chorine, when exposed to high temperatures, vaporize from feedstocks, creating corrosive salt formations on boiler walls. These elements agglomerate with silica particles to create clinker formations resulting in serious performance and operating problems for boilers. The problem of clinker formation is now being minimized through new designs in combustion systems that create a "staged combustion" where initially low combustion temperatures are used that are below the melting point of the ash in the feedstock causing the gases to be released from the fuel while retaining the chemical components in the ash. A reduced amount of air is used through the fuelbed to minimize the release of alkali components from the fuelbed. The gases are then subjected to higher temperature combustion and turbulence to create a clean combustion process. The ash produced is continually moved along the fuel bed and deposited into an ash pan or bin.

Sources of agricultural fuels for combustion.

There are four main sources of agricultural fibre sources in Canada: field crop residues, feed grains, crop milling residues and dedicated energy crops. The main factors influencing feedstock selection are price, supply and combustion properties. In recent years there has been considerable interest in using low cost feed grains, especially in smaller pellet stoves and boilers. But with increasing farm commodity prices there is now rising interest in feedstocks that have even lower prices than grain corn which can typically cost from $180-200/tonne or about $12/GJ.

The most active new biomass resources being developed in Canada with acceptable fuel quality are crop milling residues and energy grasses such as switchgrass. Field crop residues are generally the cheapest and most widely available raw material but are the most problematic for combustion. For example, Canadian wheat straw typically can contain 6.5-10.0% ash, with 1% potassium and 0.4% chlorine (Samson et al., 2000). Corn stalks also represent another large raw material source but are also high in potassium and difficult to dry. In Denmark, target values for potassium and chlorine content for power generation from herbaceous biomass are 0.2% and 0.1% respectively (Sander 1997). Straw pellets are mixed with wood pellets in some power plants in Denmark to enable use of the high-ash material.

The main crop milling residues being commercially developed for bioheat are wheat bran, oat hulls and flax shives. These are generally all dry, uniform and have moderately low potassium and chlorine contents. As well there is some use of corn cobs, barley hulls and sunflower hulls. The production of milling residues from grain milling in Canada is estimated at approximately 1.5 million tonnes (Samson et al., 2006). There currently is rising competition for this resource between the agri-fibre fuel pellet and livestock feed industry. In the winter heating season of 2006-2007, Ontario crop milling residue pellets sold for about $110-120/tonne to the greenhouse heating industry. This represents a fuel cost of about $6/GJ, compared with natural gas which is sold in the range of $9-10/GJ. The development of agri-fibre bioheat is being strengthened by the peaking of North America's gas supply and the increasing reliance on imported liquefied natural gas.

Native, perennial warm season energy grasses appear to be the next wave of agri-fibre pellet fuel development. Throughout eastern Canada, farmers are now testing production areas of these grasses. Switchgrass and big bluestem are the two main tallgrass prairie species that are being used in North America. In the prairie provinces, prairie sandreed has better adaptation than switchgrass and big bluestem to the drier areas. Switchgrass typically can produce 9-10 tonne/ha

on soils in eastern Canada of moderate productivity. A harvest in late fall, winter and in early spring can be realized in the various regions of Canada.

Delayed harvesting of these grasses can provide significant improvements in the fuel quality of grass feedstocks as the chlorine and potassium is leached from the material over time. A new system of delayed harvest is being optimized that involves fall mowing of the grass followed by spring baling. New technological innovations in high volume mowing and baling are also helping to improve biomass logistics while reducing energy use and production costs. Typically grass production costs are about $75/tonne in eastern Canada while pelleting costs are $35-$50/tonne. The main reason for pelleting herbaceous biomass is to improve convenience of handling, improve combustion efficiency, reduce particulate loads and reduce fire risks. The energy content of warm season grasses is about 18.5-19GJ/tonne or about 5-7% below wood residues on an equivalent moisture basis (Samson et al., 2005). The ash content is approximately 3-5% in Eastern Canada and 5-9% in Western Canada.

Business Development Challenges and Opportunities

Currently there is significant activity in the development of agri-fibre pellet plants in Canada. Some producers are using existing feedmill pellet plants to produce crop milling residue pellets for the commercial heating market. Others are securing export pellet markets to European power plants with minimum bulk shipments of about 7000 tonnes per load. Typical land rents near the coastal regions of the Netherlands and Germany are $1000-1200 euro/ha or $1500-$1800/ha. Importing Canadian pellets is a significantly cheaper option than growing energy crops in these regions. It costs an estimated $35-50/tonne for ocean transport from the Great Lakes region. The main advantages of developing export pellet markets are strong demand and higher prices due to European carbon trading systems, and better year-round cash flow than relying only on the domestic heating market.

A typical bioheat pellet plant that can process approximately 100,000 tonnes per year costs an estimated $7 million dollars. This represents a significantly smaller investment than what is required for a grain or cellulosic ethanol plant. Another advantage of an agri-fibre pellet plant is that it utilizes marginal farmland which typically has low cash receipts. The development of energy grasses and the bioheat industry could significantly strengthen farming and rural employment opportunities in Canada. As carbon trading systems evolve, new market development opportunities will occur with energy intensive industries such as the cement, steel and food processing industries. Other strategic markets are large commercial and institutional buildings such as schools, universities, correctional facilities, hospitals and churches as well as combined heat and power plants in northern communities.

In addition, agri-fibre pellet exports to Europe could stimulate the emergence of a large industry in eastern Canada. In Ontario and Quebec it has been estimated that 14.1 million tonnes of energy grass pellets could be produced from converting 20% of the marginal cropland and 40% of the land currently in forage production (Samson et al., 2006). This could result in the establishment of an estimated 52 pellet plants in Quebec and 89 in Ontario, requiring a capital investment of approximately $1 billion and creating revenues of an estimated $1.7 billion annually.

It appears that the use of biomass pellets in domestic commercial heating applications and for European power plants and commercial heating applications represents the best current market opportunities. In Ontario, there may be promising opportunities for biomass use in combined heat and power production with renewable energy incentives for green power in the province. Overall, power prices in Canada appear too low to see the use of herbaceous biomass co-fired in coal plants in the near-term. Export of western cereal straw pellets to Europe for power generation may be a more feasible commercial opportunity for the developing power sector.

References

Samson, R.A., S. Bailey and C. Ho Lem. 2006. Biomass resources options: Creating a BIOHEAT supply for the Canadian greenhouse industry. Phase I research report to Natural Resources Canada. 38 pp.

Samson, R., Drisdelle, M., Mulkins, L., Lapointe, C. and P. Duxbury. 2000. The use of switchgrass biofuel pellets as a greenhouse gas offset strategy. Bioenergy 2000. Buffalo, New York, October 15-19, 2000. 10pp.

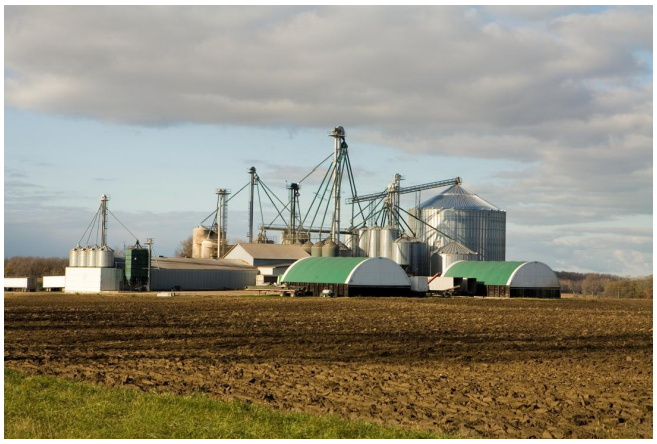
Samson, R., Mani, S., Boddey, R., Sokhansanj, S., Quesada, D., Urquiaga, S., Reis, V. and C. Ho Lem. 2005. The potential of C_4 perennial grasses for developing a global BIO-HEAT industry. Critical Reviews in Plant Science 24: 461-495.

Sander, B. 1997. Properties of Danish biofuels and the requirements for power generation. Biomass and Bioenergy 12: 177-183.

On-Farm Applications of Agri-fibre Fuels

Nott Farms
Don Nott Email: dnott@tcc.on.ca
RR 4 Clinton, ON N0M 1L0; Tel.: 519-233-7579; Fax: 519-482-5644

Nott Farms operates an oat processing facility that provides them with a by-product of oat hulls. In 2006, Don Nott began using this material along with purchased wheat bran to produce crop milling residue fuel pellets for heating applications. He now has a fleet of delivery trucks and a 10,000 tonne storage bin to hold this winter heating fuel. Nott Farms supplies approximately 20 greenhouses in Ontario with their winter heating fuel. For more information, please refer to the Better Farming Cover Story December 2006 http://www.betterfarming.com/2006/bf-dec06/cover.htm.



Nott Farm facilities in Clinton, ON (Photo courtesy of Better Farming Magazine).

K&K Greenhouses Ltd
Ken & Karen Tigchelaar Email: kkg@sympatico.ca
1852 6th Concession W, Branchton, ON; Tel.: 519-623-7688

K&K Greenhouses have installed a multi-fuel Decker Brand Boiler, produced by Decker Manufacturing Ltd. The system was installed in February 2005 and uses crop milling residue pellets, corn kernels and off-specification canola. The multi-fuel boiler is the primary heat source for their 0.75 ha greenhouse and Ken Tigchelaar is now a dealer for the Decker Brand Boiler in Ontario. For more information, please refer to the Better Farming Cover Story January 2006 **http://www.betterfarming.com/2006/bf-jan06/cover.htm.**

K&K Greenhouses Ltd. in Branchton, Ontario and their Decker Brand Boiler.

Grove Wood Heat Inc.
c/o Vince Court Email: grovewoodheat@pei.sympatico.ca
935 Pleasant Grove Rd., York, Prince Edward Island C0A 1P0 Tel.: 902-672-2090

Grove Wood Heat has been supplying wood residue boilers into the Eastern Canadian market for the past 20 years. In 2005 they began developing specialty burners to efficiently utilize off-specification barley and other feed grains. They are currently producing cereal grain burning boilers in the 25-250 kW range. A 75 kW cereal grain burner is shown installed in a small building to minimize fire risk.

A small building (with outside fuel hopper) houses a 75 kW cereal grain combustion unit made by Grovewood Heat of Little York, PEI.

Prairie Bio-Energy Inc. www.prairiebioenergy.com
P.O. Box 560, La Broquerie, Manitoba R0A 0W0; Tel.: 204-424-5313; Fax: 204 424-5405

Prairie Bioenergy was the first company in Canada to sell densified agri-fibre fuels. They currently produce a blended product made of flax shives, wood residue and waste paper products using a cooper cuber (www.cooperequipmentinc.com). The product is 2.2 cm (7/8") cube, 5-6% moisture and has a bulk density of approximately 550 kg/m^3. The primary components of the fuel cubes include a mixture of wood by-products and flax shives. The energy content is approximately 18.4 GJ/tonne. It is being sold to displace coal, mainly in commercial boilers used in large livestock barns and greenhouses.



In 2005, Prairie Bioenergy became the first Canadian producer of densified crop residues for energy. Their biomass cubes are loaded into an overhead bin for bulk loading into trucks.


Front view of the Blueflame Stoker Boiler. Vanderveen Greenhouses in Carman, MB use three units that burn flax shives to heat their 2.4 ha greenhouse facility.

Vanderveen Greenhouses
P.O. Box 957, Carman MB R0G 0J0; Tel.: 204-745-3534; Fax: 204-745-3920

Vanderveen greenhouses of Carman Manitoba is one of the first installations in Canada to successfully burn a crop residue in a bulk form for a large commercial heating application. In the winter of 2005, they installed 2 blueflame stokers (www.blueflamestoker.com) of 2.9 MW thermal output to provide 5.8 MW of base load heating from biomass for their greenhouse facility. In 2006 they expanded and added an additional 3.5 MW system. Their fuel source is flax shives, a by-product of flax straw processed for the pulp and paper industry. The flax shive is stored in a large shed adjacent to the boiler room and uses a "Walking Floor" for fuel delivery to the main conveyor.

Major Suppliers of Combustion Technology in Canada

Combustion Companies

Blue Flame Stoker www.blueflamestoker.com
Box 285, Headingley, MB R4J 1C1; Tel.: 204-694-2398; Fax: 204-697-7535; Email: info@blueflamestoker.com
Models from 800kw to 3500kw

Decker Brand Boilers www.deckerbrand.com
General Delivery, Decker, Manitoba, R0M 0K0 Tel.: 204-764-2861; Fax: 204-764-2594
Email: clarence@dekkerbrand.com *8 models from 44kw to 1025kw.*

Grove Wood Heat Inc. grovewoodheat@pei.sympatico.ca
c/o Vince Court, 935 Pleasant Grove Rd., York, Prince Edward Island C0A 1P0 Tel.: 902-672-2090
Boilers from 25-250kw.

Harman Stove Company http://www.harmanstoves.com
352 Mountain House Road, Halifax, Pennsylvania 17032; Tel.: 717-362-9080; Fax: 717-362-4251
Small scale central heating and hot air pellet furnaces

Pro-Fab Industries Inc http://profab.org/Products/Pelco.aspx
P.O. Box 112, Arborg MB R0C 0A0, Tel.: 888-933-4440; Fax: 204-364-2472; Email: info@profab.org
Hot water Pelco Boiler, three sizes from 220kw, 440kw and 740 kw

Vidir Biomass Systems Inc. www.vidir.biz/index-biomass.htm
Box 700 Arborg, MB R0C 0A0 ; Tel.: 800-210-0141; Fax: 204-364-2454
Models range from 1200 kw to 4690 kw units www.kap.mb.ca/altenergy_presentations.htm *(see opportunities in biomass-Eric Remple~vidar machine)*

Pelleting Technology

Amandus Kahl GmbH & Co. KG http://www.akahl.de/index.php?hid=34
Dieselstrasse 5, D-21465 Reinbek, Germany; T:+49-40-72771-0 ; F:+49-40-72771-100
E: info@amandus-kahl-group.de *Production of plants for pellets from wood, sawdust, straw, and other organic residual products*