The Potential for Biomass Energy Crop Production in Canada

Roger Samson
Resource Efficient Agricultural Production (REAP)-Canada
www.reap-canada.com

REAP-Canada

- Providing leadership in the research and development of sustainable agricultural biofuels and bioenergy conversion systems for greenhouse gas mitigation
- 14 years of R & D on energy crops for liquid and solid biofuel applications
- Working in China, Philippines and West Africa on bioenergy and rural development projects
Today’s Seminar

- Relative efficiency of annual field crops, vs biomass energy feedstocks as “solar energy collectors”
- Review some of the bioenergy feedstock development research in Canada
- Energy Production Potential of the Industry
- Future research needs

Optimizing Biofuel Development

To economically provide large amounts of renewable energy from biomass we must:

1. As efficiently as possible capture solar energy over a large area
2. Convert this captured energy as efficiently as possible into a convenient and low cost end use application
Solar Energy Collection and Fossil Fuel Energy

Energy (GJ) per hectare

- Rye
- Oats
- Canola
- Soybeans
- Barley
- Winter wheat
- Tame Hay
- Grain Corn
- Switchgrass

Energy Content of Crop per Hectare less Fossil-Fuel Energy Consumption
Fossil Energy Consumption per Hectare Production

Biofuels Research at REAP-Canada
Switchgrass: a multi-use biomass crop

- Paper
- Cellulosic ethanol
- Biofuel pellets and briquettes
- “Straw bale” Housing

Grass Pellet Burning Stoves
Comparing C3 and C4 plants

**Cool season (C3) Plants**
- Greater chilling tolerance
- Utilize solar radiation effectively in spring and fall

**Warm season (C4) Plants**
- Higher water use efficiency (typically 50% higher)
- Can utilize solar radiation 40% more efficiently under optimal conditions
- Improved biomass quality: lower ash and increased holocellulose and energy contents
- Responsive to warming climate
Warm Season Grasses

C4 Grasses such as Switchgrass (*Panicum virgatum*), are ideal bioenergy crops because of their moderate to high productivity, stand longevity, high moisture and nutrient use efficiency, low cost of production and adaptability to most agricultural regions in North America.
Water as a factor limiting yield

- Ontario and Quebec receive 1000 mm/yr
- Assumption that 40% of water is available for crop growth: 400 mm/yr
- Assume C4 species use 20 mm/tonne
  Assume C3 species use 40 mm/tonne
- Maximum yield C4 species: 400/20 = 20 tonnes
  Maximum yield C3 species: 400/40 = 10 tonnes

Native Range of Promising Warm Season Grass Biomass Feedstocks
Yield of switchgrass cultivars at Ste. Anne de Bellevue, Quebec (1993-1996)

Mean Annual Biomass Production of 7 Grasses in 3 Provinces of Western Canada (3 or 4 yr averages).

<table>
<thead>
<tr>
<th>Species</th>
<th>Cultivar or line</th>
<th>Brandon clay soil</th>
<th>Brandon sandy soil</th>
<th>Lethbridge</th>
<th>Swift Current dryland</th>
<th>Swift Current irrigation</th>
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</thead>
<tbody>
<tr>
<td>Cool-season grasses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickspike wheatgrass</td>
<td>Crittan'</td>
<td>7.2</td>
<td>1.2</td>
<td>6.7</td>
<td>2.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Lodom'</td>
<td>4.8</td>
<td>1.6</td>
<td>7.5</td>
<td>2.0</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Green needlegrass</td>
<td>ND-691</td>
<td>10.5</td>
<td>2.4</td>
<td>15.8</td>
<td>2.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Mammoth wildrye</td>
<td>Rodan'</td>
<td>6.9</td>
<td>2.0</td>
<td>7.7</td>
<td>2.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Western wheatgrass</td>
<td>Rosana'</td>
<td>6.0</td>
<td>1.7</td>
<td>8.8</td>
<td>2.5</td>
<td>5.4</td>
</tr>
<tr>
<td>Warm-season grasses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big bluestem</td>
<td>Bison'</td>
<td>6.2</td>
<td>1.6</td>
<td>5.5</td>
<td>1.1</td>
<td>3.0</td>
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<tr>
<td>Switchgrass</td>
<td>Dacotah'</td>
<td>6.5</td>
<td>1.7</td>
<td>7.0</td>
<td>1.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Prairie sandreed</td>
<td>Goshen'</td>
<td>0.0</td>
<td>1.8</td>
<td>9.5</td>
<td>1.1</td>
<td>2.4</td>
</tr>
<tr>
<td>ND-95</td>
<td>0.3</td>
<td>2.2</td>
<td>7.9</td>
<td>1.4</td>
<td>3.1</td>
<td></td>
</tr>
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</table>

Jefferson et al. 2002
## Farmland in North America and Potential for Biofuel Production

<table>
<thead>
<tr>
<th>Land use</th>
<th>Millions of Hectares</th>
<th>Area for biofuel production* (million ha)</th>
<th>Potential perennial grass production** (million tonnes)</th>
<th>Solar energy collected (Billions GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>68</td>
<td>10.2</td>
<td>60.2</td>
<td>1.11</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>377</td>
<td>56.6</td>
<td>458</td>
<td>8.47</td>
</tr>
</tbody>
</table>

* Estimated 15% land converted to bioenergy grasses

** Assumed bioenergy hay yields of 5.9 tonne/ha in Canada and 8.1 t/ha in the US and 18.5GJ/tonne of hay

## Switchgrass Harvesting Operations
Economics of Switchgrass Production

- Fall harvesting $41-57_{CDN/tonne}
- Spring harvesting $46-68_{CDN/tonne}

Economic Cost Breakdown for Fall Switchgrass Production

- Establishment 3%
- Fertilization 16%
- Harvest and transport 46%
- Land rent 29%
- Labour 5%
- Misc 1%

Modernizing the Bioenergy Heat Production Chain

- Energy crop
- Pellet fuel
- Stove
- Boiler
- Heating Cooking
Relative Energy Use in Switchgrass Production

0.8GJ/tonne
23:1 Energy Output:Input Ratio
Bale processing at a pellet mill
Energy Associated with Switchgrass Pellet Fuel Cycle

- Switchgrass establishment
- Field Production and Transport
- Pellet Manufacturing and Distribution
- Pellet mill construction
- Pellet mill operation
- Management, sales, billing and delivery of pellets
- Switchgrass transportation
- Switchgrass harvesting
- Switchgrass fertilization and application

Energy Output:Input Ratio 14:1
### Net Energy Gain and Land Use Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Switchgrass fuel pellets</th>
<th>Co-firing switchgrass with coal</th>
<th>Switchgrass cellulosic ethanol and electricity</th>
<th>Grain corn ethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass yield per hectare (ODT)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>6.5</td>
</tr>
<tr>
<td>Direct biomass energy yield (GJ/ha)</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>136.5</td>
</tr>
<tr>
<td>Energy yield after conversion (GJ/ha)</td>
<td>175.8</td>
<td>58.3</td>
<td>73.0 (67.2 ethanol + 5.8 electricity)</td>
<td>64.2+ coproducts</td>
</tr>
<tr>
<td>Energy consumed in production &amp; conversion (GJ/ha)</td>
<td>12.7</td>
<td>11.1</td>
<td>15.9</td>
<td>42.8+ coproducts credits</td>
</tr>
<tr>
<td>Net energy gain (GJ/ha)</td>
<td>163.1</td>
<td>47.2</td>
<td>57.1</td>
<td>21.4</td>
</tr>
</tbody>
</table>

### BIOHEAT: is the best way to use farmland to reduce GHG’s

- In Ontario Bioheat from grasses is 7 times more efficient than using land to produce corn for ethanol
- Switchgrass Cellulosic ethanol is 2.7 times more effective than corn ethanol
- Corn ethanol is a subsidy to US corn farmers as Canada is a net corn importer
- Corn ethanol is weak GHG and rural development policy
New Advances in Pellet Combustion Technologies

- Gasifier Pellet stove and boilers can have 85% efficiency and can burn densified switchgrass fuels

Space and Water Heating in the Residential Sector by Type of Building in Ontario (2001)

![Energy Use (PJ) chart showing energy usage for different types of buildings: Single Detached, Single Attached, Apartments, Mobile Homes. The chart indicates high energy use for Single Detached and lower use for other types of buildings.]
Residential Space and Water Heating Energy Use in Ontario (2001)

Average Annual Energy Expenditures (millions$) for Domestic Space Heating in Ontario (Jannasch et al 2001)
The Main Fuel in Use is Natural Gas, but where are Natural Gas Prices Headed in North America?

Residential Prices of Natural Gas, USA, in US Dollars per Cubic Metre, 1981-2004

Comparative Costs of Hay Prices vs. Residential Heating Costs in Manitoba
On-Farm Energy in the Prairies at $5.50/GJ

- Energy grasses grown for $55/tonne or $3/GJ
- Densification at $45/tonne or $2.50/GJ
- On-farm fuel at $100/tonne or $5.50/GJ
- Cheap rural energy will stimulate the entire rural economy

PFI Pellet Fuel Quality Standards

- Premium (<1% ash) vs. Standard (3% ash)
- Density: 40 pounds per cubic ft.
- Dimensions: Maximum 1.5 inches in length 
  Diameter ¼ or 5/16 in.
- Fines: Maximum 0.5% by weight
- Chlorides: Maximum 300 ppm
Biomass quality of switchgrass as a combustible biofuel

The formation of clinker is a concern when combusting herbaceous feedstocks such as switchgrass pellets. Late fall harvesting and overwintering warm season grasses reduces the potassium and chlorine content which improves overall biomass quality to enable combustion in commercial boilers.

Spring harvested switchgrass: 2.8-3.2% ash and 19.1GJ/tonne
Fall harvested switchgrass: 4.5-5.2% ash and 18.5 GJ/tonne
Western wheat straw: 7-11% ash and 17.5-18 GJ/tonne
Wood residues: .5-3% ash and ~19.5 GJ/tonne

Also Crop Milling Residues

- Oat hulls, pin oats, wheat midds, flax shives, sunflower hulls are all excellent low cost fuels for pellets/cubes
- These fuels will create the market for energy grasses to follow
- These fuels can be developed in 2006 at <$100/tonne and are the low hanging fruit for developing the emerging bioheat industry
- The main reason field crop residues will be slower to develop are the high ash, chlorine and potassium content
Main Market Opportunities for energy grasses and crop milling residue fuels

- Residential stoves and boilers 9-25 kw (though not quite as fuel friendly as bigger units)
- Small commercial boilers 100-300kw (few combustion limitations, most units now with ability to burn most higher ash fuels due to advancing technology)
- Industrial boiler biofuel markets, few technical problems but will greatly benefit from carbon credits especially in western Canada (Kyoto should become a favourite word of farmers!)

Estimated Cost of Heating in Ontario (2006)

![Cost of Heating in Ontario Graph]
**Estimated Cost of Heating in Ontario with coal (2006)**

![Graph showing estimated costs for different fuels.](image)

**Estimated Cost of Heating in Ontario (2006)**

<table>
<thead>
<tr>
<th>Conventional Fuel</th>
<th>Cost per Unit</th>
<th>Unit</th>
<th>Energy Content</th>
<th>Cost per GJ</th>
<th>Efficiency</th>
<th>Cost per GJ</th>
<th>Cost for 1000 GJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Oil</td>
<td>$0.60</td>
<td>Litre</td>
<td>0.039</td>
<td>$16.12</td>
<td>80%</td>
<td>$20.15</td>
<td>$20,145</td>
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<tr>
<td>Natural Gas</td>
<td>$0.50</td>
<td>m³</td>
<td>0.037</td>
<td>$13.43</td>
<td>85%</td>
<td>$15.80</td>
<td>$15,800</td>
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<tr>
<td>Coal</td>
<td>$220</td>
<td>tonne</td>
<td>31.8</td>
<td>$6.92</td>
<td>80%</td>
<td>$8.65</td>
<td>$8,648</td>
</tr>
<tr>
<td>Grain Corn</td>
<td>$150</td>
<td>tonne</td>
<td>15.8</td>
<td>$9.49</td>
<td>80%</td>
<td>$11.87</td>
<td>$11,867</td>
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<tr>
<td>Switchgrass Pellets</td>
<td>$160</td>
<td>tonne</td>
<td>18</td>
<td>$8.89</td>
<td>80%</td>
<td>$11.11</td>
<td>$11,111</td>
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<tr>
<td>Agri-fibre Pellets</td>
<td>$140</td>
<td>tonne</td>
<td>18.1</td>
<td>$7.73</td>
<td>80%</td>
<td>$9.67</td>
<td>$9,668</td>
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<tr>
<td>Corn Cobs</td>
<td>$80</td>
<td>tonne</td>
<td>18</td>
<td>$4.44</td>
<td>70%</td>
<td>$6.35</td>
<td>$6,349</td>
</tr>
</tbody>
</table>
Carbon credits for biomass can make it cheaper than coal

- Since burning 1 tonne of biomass displaces emissions of ~1.2, 1.5 and 2 tonne from combustion of natural gas, oil, and coal
- Carbon credits of ~10/tonne CO2 avoided could be worth up to $20/tonne of biomass
- Carbon trading system could reduce users cost of biomass by ~10-15%
Summary

- Direct Combustion of densified fuels represents the best biofuel cycle in terms of energy, land use, and economics.
- Could provide a substantial new GHG friendly energy resource for North America to displace declining fossil fuel reserves.
- Emission reductions in Canada could be ~100 million tonnes.

Summary (continued)

- Perennial grasses hold the potential to become Canada’s largest new renewable energy source.
- The federal government should encourage the development of 10-15 million ha of perennial forages for biofuel applications.
- The farmers in Canada and the US could produce more than 500 million tonnes of energy crops annually.
- Energy equivalent is ~1.5 billion barrels of oil equivalent or 4 million barrels/day.
Time to get the message out!

- Bioheat is a “made in Canada” GHG solution that greatly benefits rural Canada
- Energy crop farming will absorb the surplus production capacity of the farm sector and cause an across the board rise in commodity prices
- North American farmers can out produce the Tarsands within the next 25 years
- We need to sow the seeds of a GREEN PROSPERITY movement to keep our economy and biosphere healthy