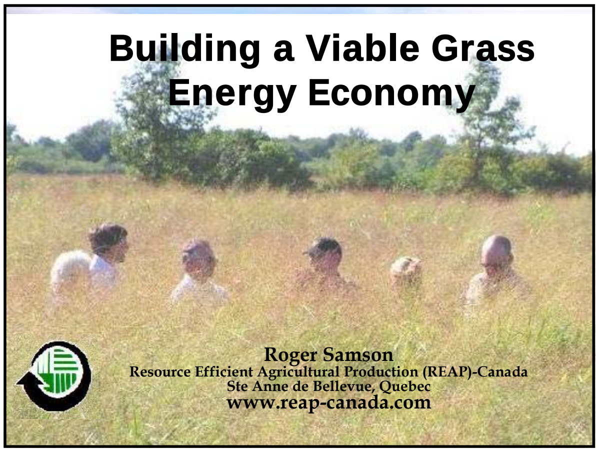
Building a Viable Grass Energy Economy



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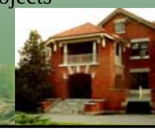
REAP-Canada

- Providing leadership in the research and development of sustainable agricultural biofuels and bioenergy conversion systems for greenhouse gas mitigation
- 18 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



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Bioenergy Follows the Emergence of Food Production Systems

- 10,000 years ago humans learned to grow food from the land as a response to exhaustion of food supplies from hunter gatherer lifestyle
- Today bioenergy is emerging as a response to exhaustion of fossil energy supplies
- One of the greatest challenges of humanity is to create resource efficient bioenergy systems from our agricultural lands

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Optimizing Bioenergy Development for Energy Security

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 useful energy forms for energy consumers

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Biofuels Research at REAP-Canada began in 1991

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

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Warm Season Grasses
C4 Grasses such as switchgrass 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 marginal soils.
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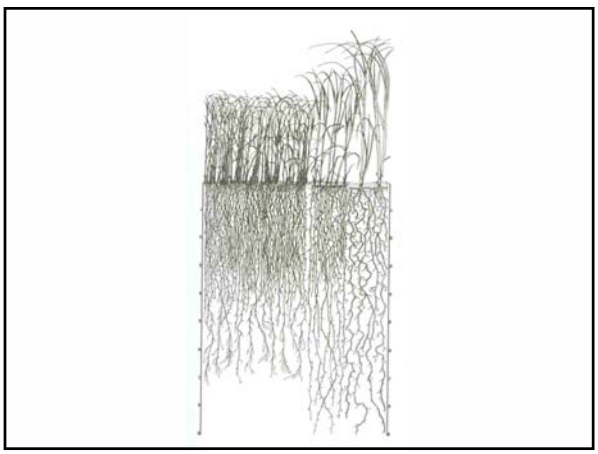
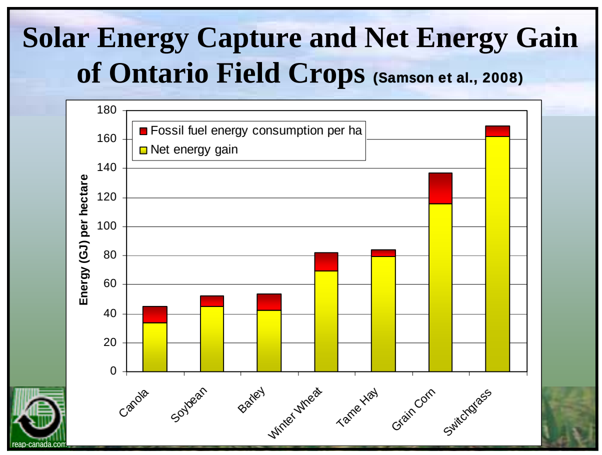
Big Bluestem
in New York




Solar Energy Capture and Net Energy Gain of Ontario Field Crops (Samson et al., 2008)
Fossil fuel energy consumption per ha
Net energy gain
Energy (GJ) per hectare
180
160
140
120
100
80
60
40
20
0
Canola
Soybean
Barley
Winter Wheat
Tame Hay
Grain Corn
Switchgrass
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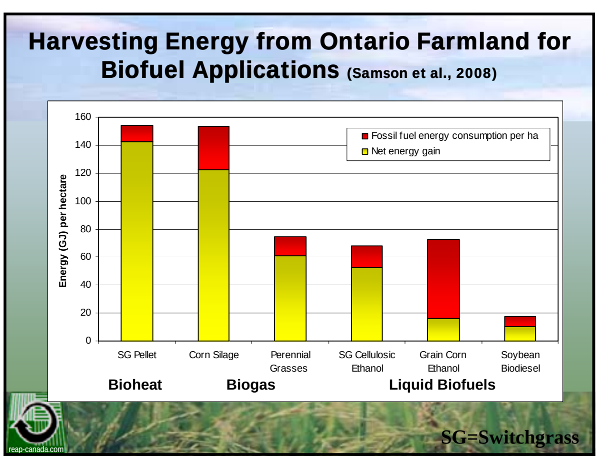
Harvesting Energy from Ontario Farmland for Biofuel Applications (Samson et al., 2008)
Fossil fuel energy consumption per ha
Net energy gain
Energy (GJ) per hectare
160
140
120
100
80
60
40
20
0
SG Pellet
Corn Silage
Perennial Grasses
SG Cellulosic Ethanol
Grain Corn Ethanol
Soybean Biodiesel
Bioheat
Biogas
Liquid Biofuels
SG=Switchgrass
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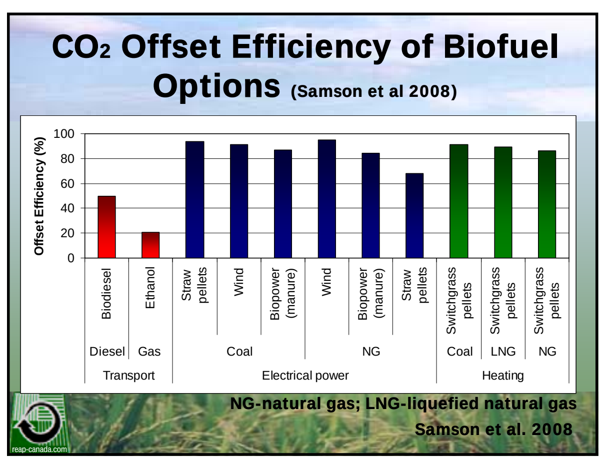
CO2 Offset Efficiency of Biofuel Options (Samson et al 2008)
Offset Efficiency (%)
100
80
60
40
20
0
Biodiesel
Ethanol
Straw pellets
Wind
Biopower (manure)
Wind
Biopower (manure)
Straw pellets
Switchgrass pellets
Switchgrass pellets
Switchgrass pellets
Diesel
Gas
Coal
NG
Coal
LNG
NG
Transport
Electrical power
Heating
NG-natural gas; LNG-liquefied natural gas
Samson et al. 2008
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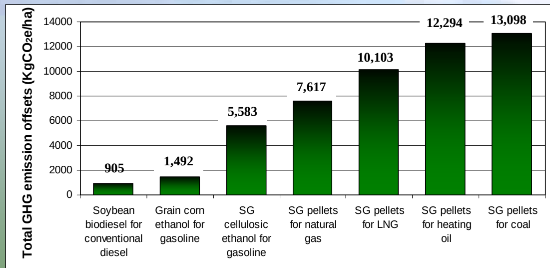
GHG Offsets From Ontario Farmland Using Biofuels (Samson et al 2008)



SG=Switchgrass; LNG=Liquefied Natural Gas

Creating a Grass Biofuel Industry

- Technology Development (grass, densification, boiler)
- Policy (renewable energy incentives and/or carbon regulations)
- Capacity Development and Consumer Education (training and awareness)
- Market Analysis and Development and Government Regulation (fuel quality and boiler emissions)

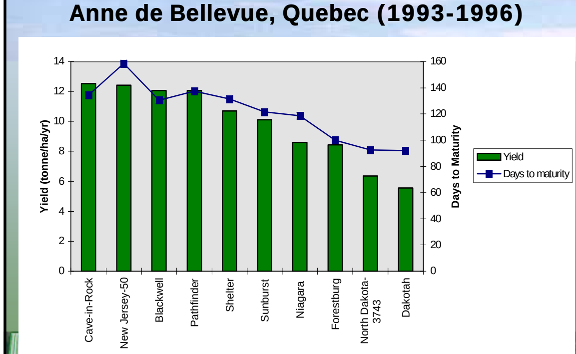
A large and efficient solar battery

1. Adaptability trials to identify cultivars and species adapted to marginal lands and cooler production zones
2. Ongoing regional plant material improvement through breeding and selection
3. Optimize best management practices for establishment and production

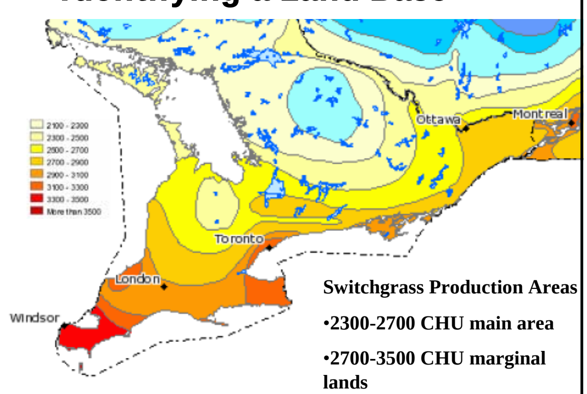
Switchgrass Management

- REAP SG Production guide
- Good site selection and weed control especially in northern locations
- Typically 50 kg N/ha and no P, K or lime
- Mow after senescence at 4” (10cm) to help ensure winter survival

Fall Yield of Switchgrass Cultivars at Ste. Anne de Bellevue, Quebec (1993-1996)



Identifying a Land Base



Switchgrass Production Areas

•2300-2700 CHU main area

•2700-3500 CHU marginal lands

2008 Switchgrass Varieties for Canada
(guideline for hardiness and productivity)

Maturity	Days to Maturity	Cultivar name	Cultivar Origin (state, degree)	Corn Heat Unit (CHU) requirements
Very Early	95	Dakotah	N. Dakota (46)	2200
Early	100-105	Forestburg	S. Dakota (44)	2300
Mid	115-120	Sunburst Summer	S. Dakota (44) Nebraska (41)	2400
	125	Shelter	W. Virginia (40)	2500
Late	130	Cave in Rock	S. Illinois (38)	2600
Very Late	150	Carthage	N. Carolina (35)	2700

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Farmland in Ontario & Quebec for Energy Crop Farming

	Land use	Land area ('000 ha)	Area for biofuels* ('000 ha)	Potential grass yield** ('000 tonnes)	Total potential grass yield ('000 tonnes)
Ontario	Crop land	2,254	450	4,192	**8,883**
	Forage	1,261	504	4,691	
Quebec	Crop land	940	188	1,748	**5,221**
	Forage	933	373	3,473	
				Ontario & Quebec Total	***14,104***

*Estimated 20% crop land and 40% forage land converted to bioenergy production
**Assumed yield of 9.3 tonnes/ha

Need to create efficient logistic systems

- Optimize low cost harvest and storage systems
- Best achieved through participatory research and development approaches involving progressive farmers with experience in biomass handling
- Some companies including CNH already optimizing equipment for switchgrass harvesting

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Why Use On-farm Participatory Approaches

- Ensures technology development is appropriate for end user
- Farmers believe what they see and a model energy crop farm is not the real deal
- Lowers cost of research and facilitates more rapid technology development
- Empowers the farmers through research and technology innovation

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Need Efficient Densification Technologies

- Need ongoing optimization of pellet and briquetting systems to ensure low cost and quality fuels produced
- Major advantage in capital costs of pellets/briquettes relative to other bioconversion technologies

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Reasons to Densify Herbaceous Biomass

- Convenient for handling and storage
- Increased energy density (smaller storage and combustion systems)
- Reduces fire risks
- More control over combustion
  - Higher efficiency
  - Lower particulate load

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Pelletizing Switchgrass to ensure high durability pellets

- Ideally 8-12% moisture
- fine ground using a screen of at least 7/64” (2.8 mm); ideally 3/32 (2.4 mm)
- Pellet die of L/D of 8.5-9:1 (2 ¼” thick die)
- Heat up to at least 90 degrees Celsius utilizing a high quality saturated steam
- Overwintered grass seems to be less waxy on surface and easier to make pellets or cubes

Bioenergy Capital Costs Investment Requirements

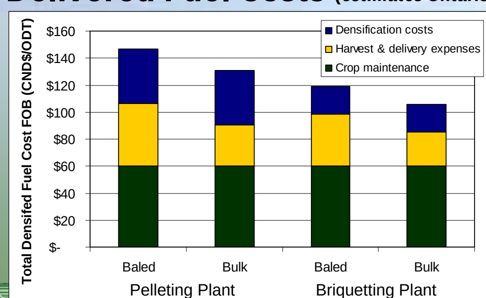
($ per GJ Output Energy plant)

Grass Pellet $5/GJ → **$6 million USD capital investment, producing 60,000 tonnes/yr**

Corn ethanol $24/GJ → **$102 million USD capital investment, producing 200 million L/yr**

Cellulosic ethanol $57/GJ → **$300 million USD capital investment, producing 250 million L/yr**

Technology Integration may lower Delivered Fuel Cost (estimates Ontario)



Samson et al., 2008

WSG Biomass Quality and Combustion

Problem:

- Main historic barrier with grasses has been high potassium (K) & chlorine (Cl)
- Causes clinker (agglomeration) problems and corrosion in boilers

Solution

- Use warm season grasses under delayed harvest management to leach chemicals
- Use advanced boiler & stove technology

Biomass Quality of Switchgrass vs. Wood Pellets and Wheat Straw

Unit	Wood pellets	Wheat straw	Switchgrass	
			Fall harvest	Overwintered Spring harvest
Energy (GJ/t)	20.3	18.6-18.8	18.2-18.8	19.1
Ash (%)	0.6	4.5	4.5-5.2	2.7-3.2
N (%)	0.30	0.70	0.46	0.33
K (%)	0.05	1.00	0.38-0.95	0.06
Cl (%)	0.01	0.19-0.51	n/a	n/a

Source: Samson *et al.*, 2005

Creating clean combustion with very low particulates

- Pelleted fuel is better than bulk fuel
- Low content of K, Cl and S essential to reduce aerosol (fine particulate) formation
- Advanced Combustion technology (lamda control, condensing boiler)
- Use cyclone on combustion appliance to capture particulates

Overall, particulate load as low as heating oil is achievable

Commercial/industrial sector:

coal use is growing and biomass can't compete without incentives

TORONTO STAR Nov 11, 2008

Grovewood Heat Boiler

75 KW heating a farm complex

9kw Dellpoint Gasifier Pellet Stove

Ash and Energy Content of Overwintered Switchgrass

Plant Component	Ash Content	Energy Content (GJ/ODT)
Stems	1.03%	19.6
Seed Heads	2.38%	19.5
Leaf Sheaths	3.07%	18.7
Leaves	6.98%	18.4

***Overall weighted SG average ash content of 2.75% and 3.25% on sandy and clay sites respectively**

Future Strategies to Improve Biomass Quality

- Increase stem content through breeding and use of alternative species like big bluestem
- Can we fractionate WSG's and send stems to residential pellet markets and higher ash plant components to commercial/industrial pellet markets?

Renewable Energy Incentives in $/GJ in Ontario, Canada (Samson et al.2008)

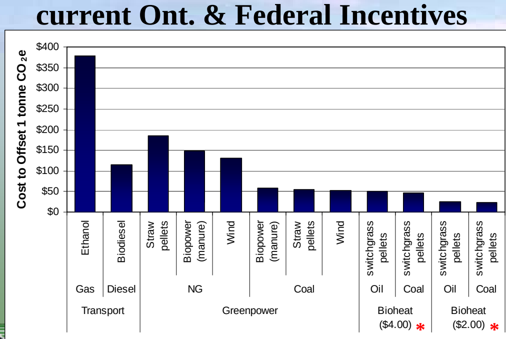
Corn Ethanol $8.00/GJ

Wind Power Incentives $15.28/GJ

Bioheat Pellets $2-4/GJ

Incentive Assumptions:
Corn Ethanol (0.021GJ/L @ $0.168/L) based on $0.10 federal + $0.068 Ontario Ethanol Fund
Wind Power (0.0036GJ/kwh @ $0.055/kWh) based on $0.01 federal + $0.045 province of Ontario
BioHeat Pellets (18.5 GJ/tonne @ $37-$74/t) currently no policy incentives are in place

Costs required to offset 1 tonne CO_2e with current Ont. & Federal Incentives



*Suggested incentive

Samson et al. 2008

Need more progressive RET and climate change policy leadership from government

- In Canada we need greater parity in the application of federal incentives (eg wind power $2.78/GJ and $5.00GJ ethanol and $5.68GJ/biodiesel and nothing for biogas or bioheat)
- If CO2 is the main policy rationale, we should use results based management approaches (ie reward technologies that appreciably reduce CO2)

Best Policy Instrument Options:

I. Modest carbon tax of $25/tonne CO_{2eq}

II. Federal 1-2-3-4-5 Renewable energy and climate change program

1. One national renewable energy incentive program
2. $2/GJ Green heat
3. $3/GJ Biogas
4. $4/GJ Liquid biofuels and green power
5. 50% reduction in GHG required to qualify for incentives

Summary and Conclusions

- Warm season grasses represent the most resource efficient way to create renewable energy and mitigate GHG through crop production
- Large potential market for space and process heat applications to replace coal, natural gas, propane and heating oil

Summary (Continued)

- There are no technical barriers to develop the grass pellet industry
- There is a policy crisis in biofuel development in North America which prevents the most efficient 2nd generation biofuel systems from emerging
- Need to increase political awareness of the need to strengthen policies to support the grass pellet industry

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