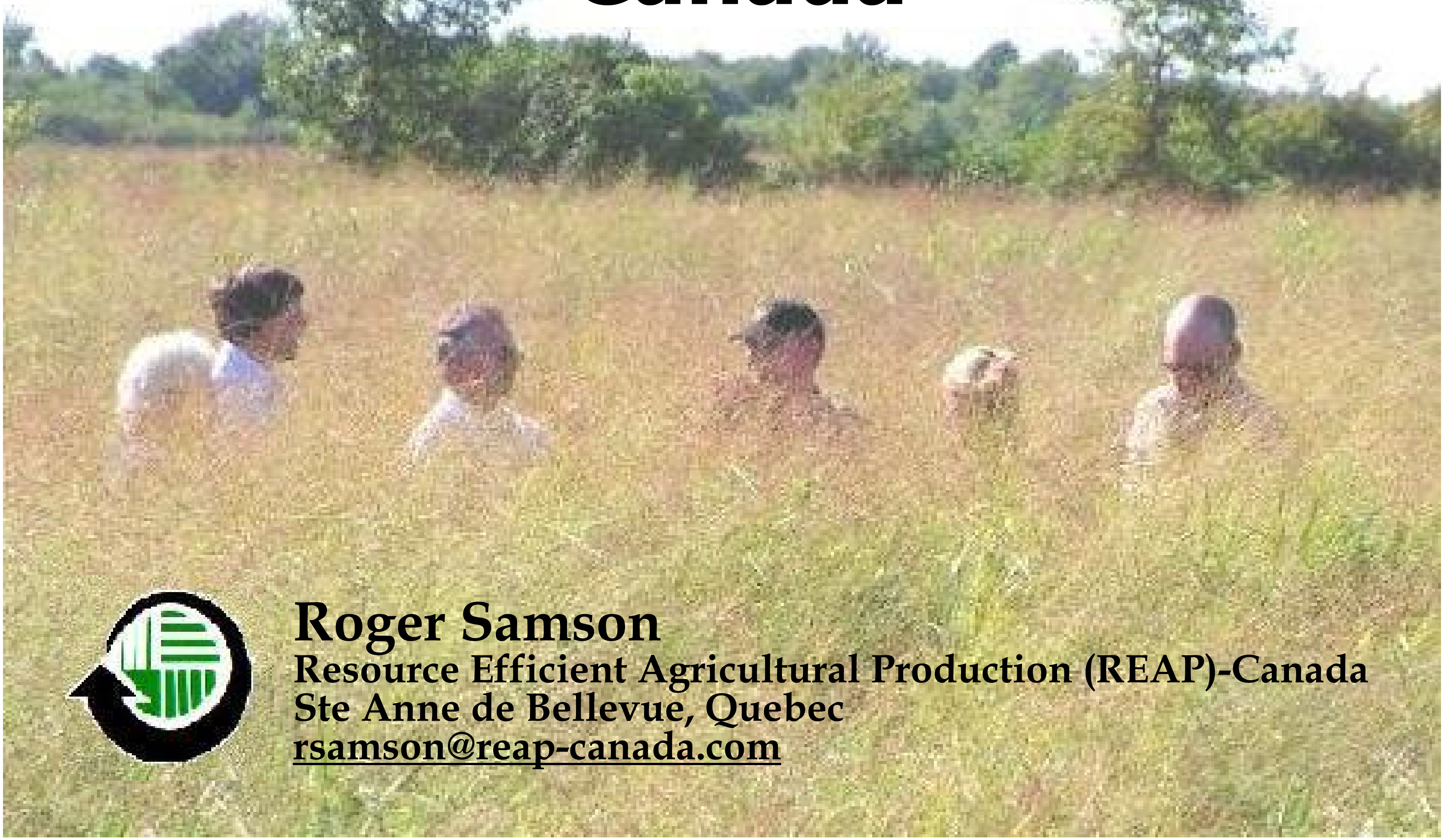
Switchgrass for BioHeat in Canada



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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
- 17 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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Optimizing Bioenergy Development for Energy Security

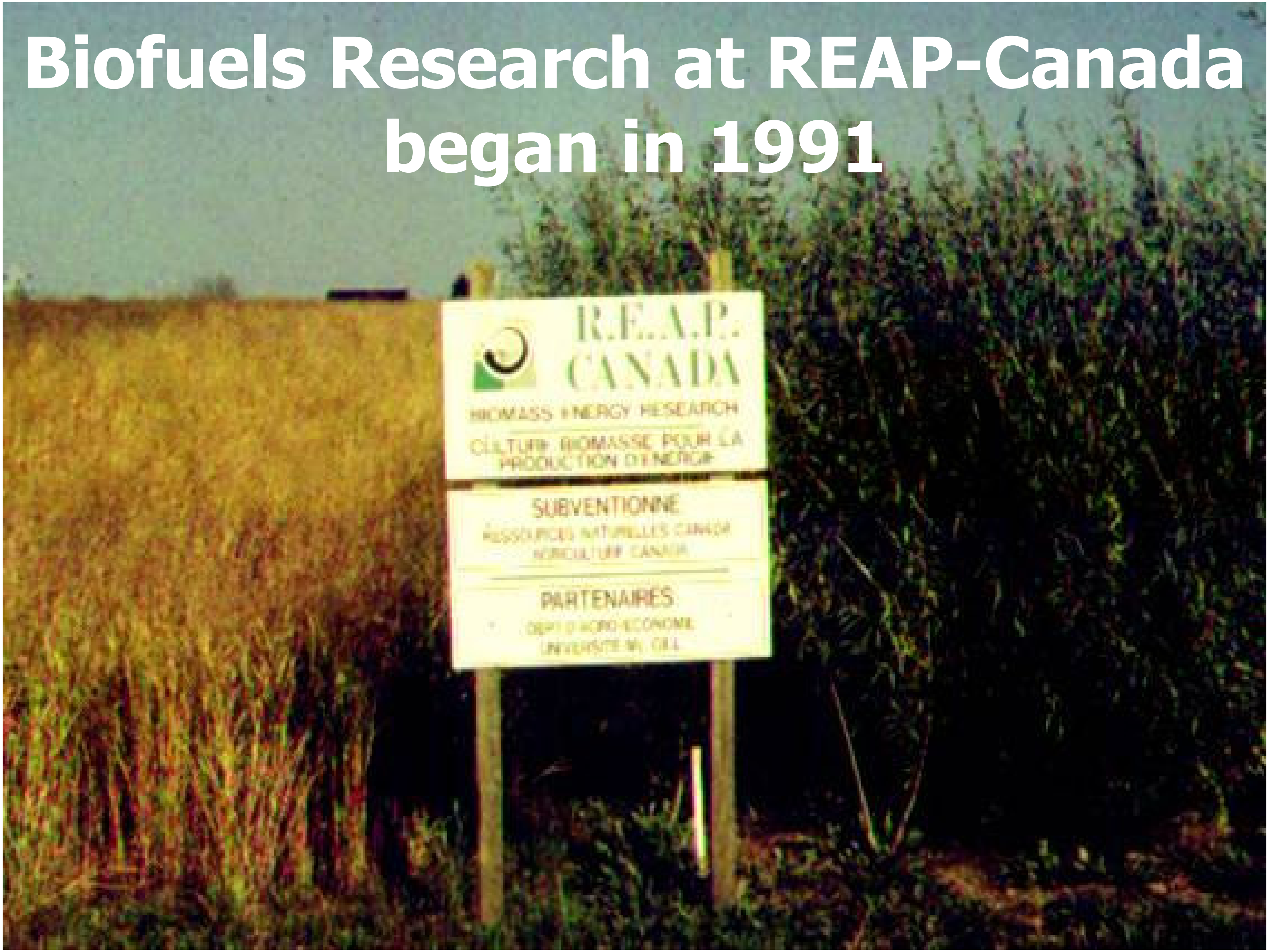
To economically provide large amounts of renewable energy from biomass we must:

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

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

Biofuels Research at REAP-Canada began in 1991



Comparing C3 and C4 plants

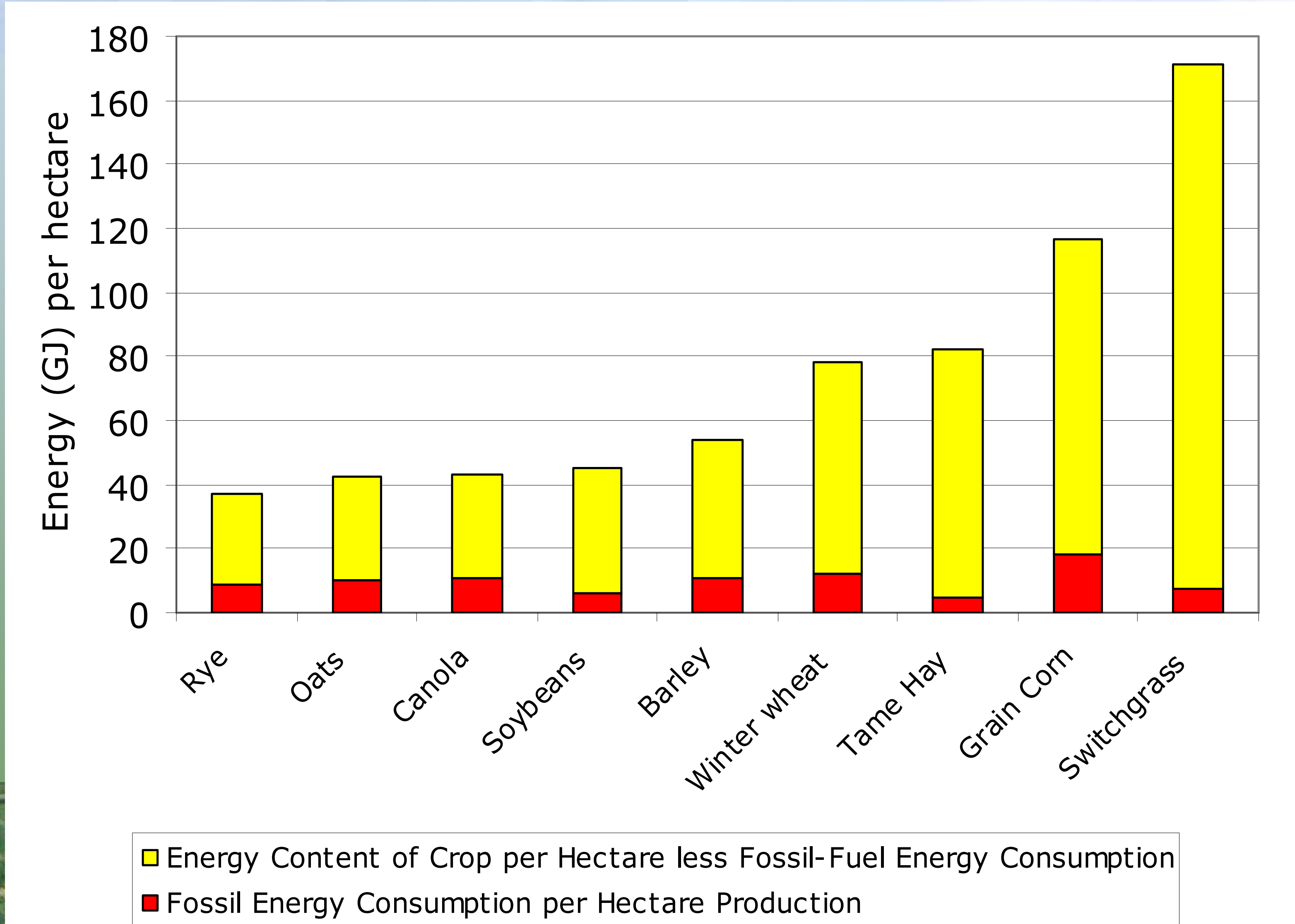
Cool season (C3) Plants

- 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

Solar Energy Collection and Fossil Fuel Energy Requirements of Ontario Crops/ha (Samson et al., 2005)



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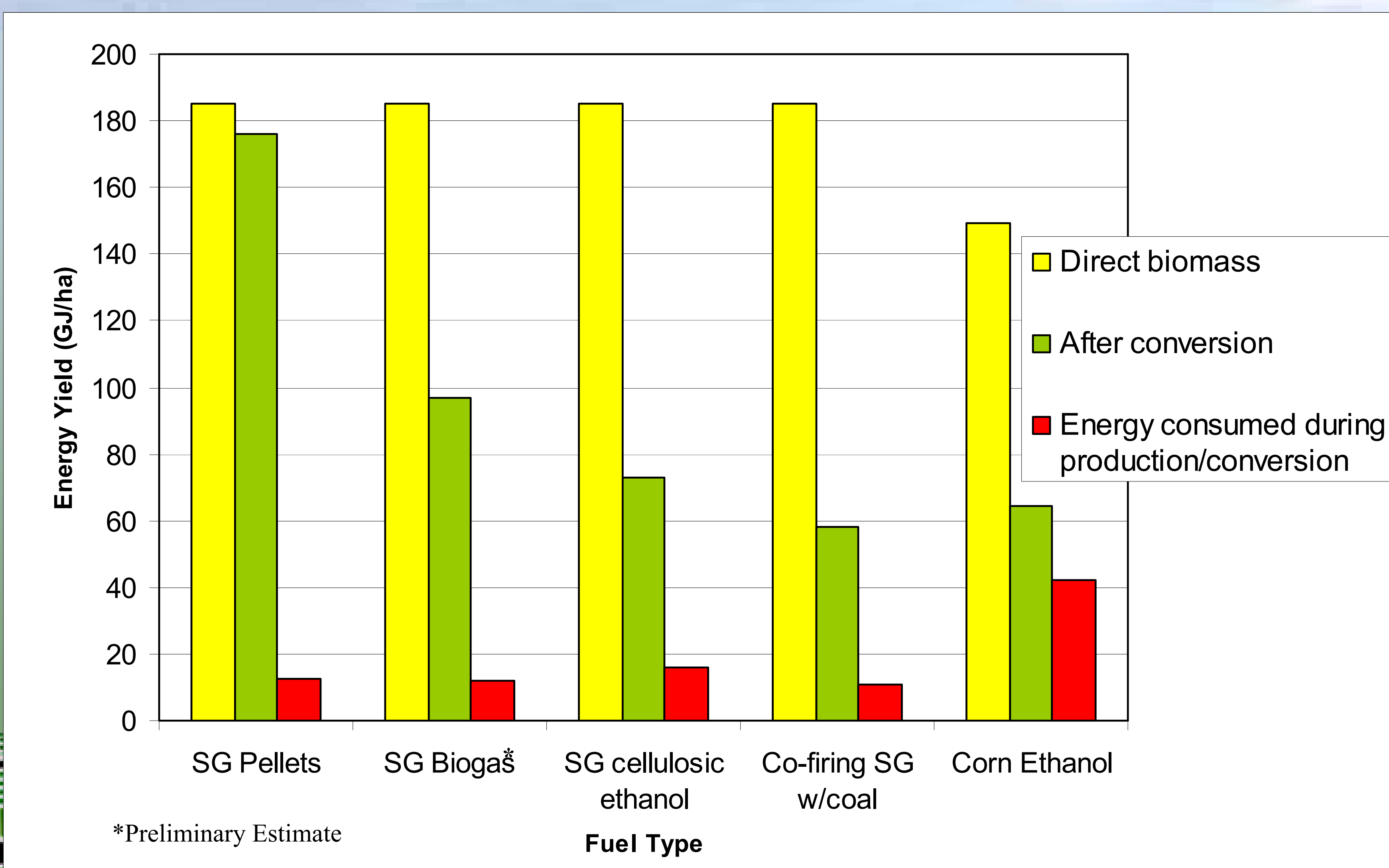
Thermodynamics of Switchgrass (SG) Energy Conversion Pathways



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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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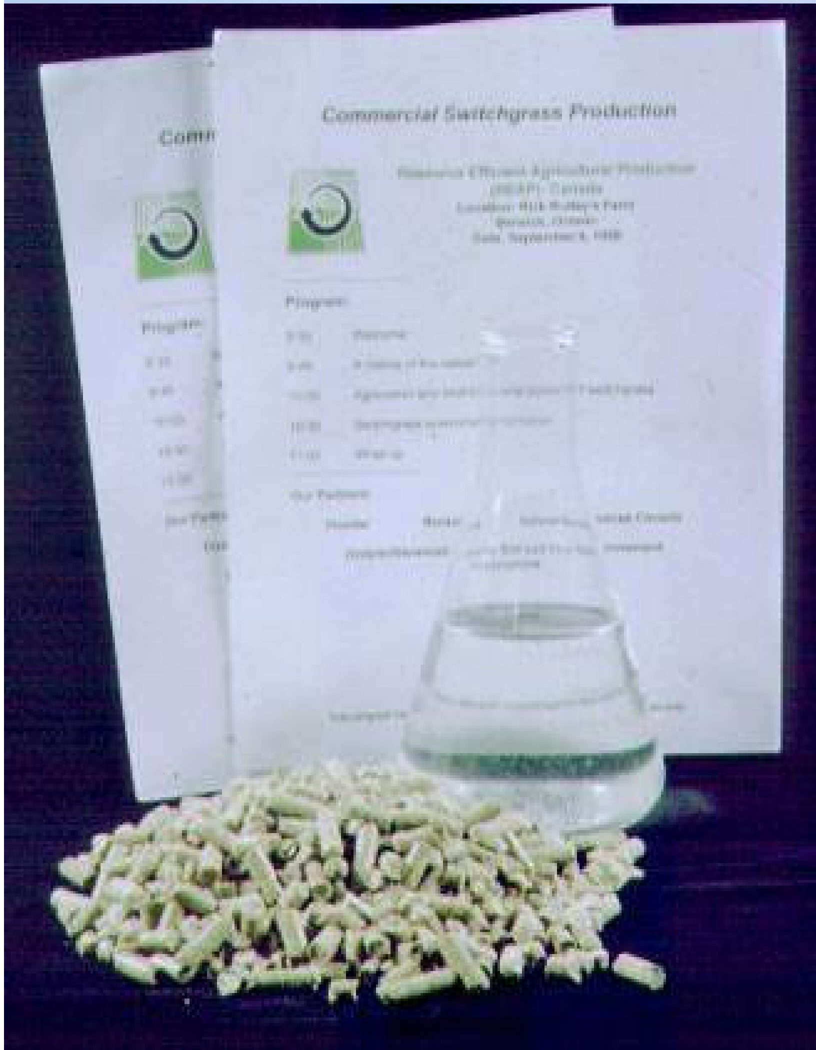
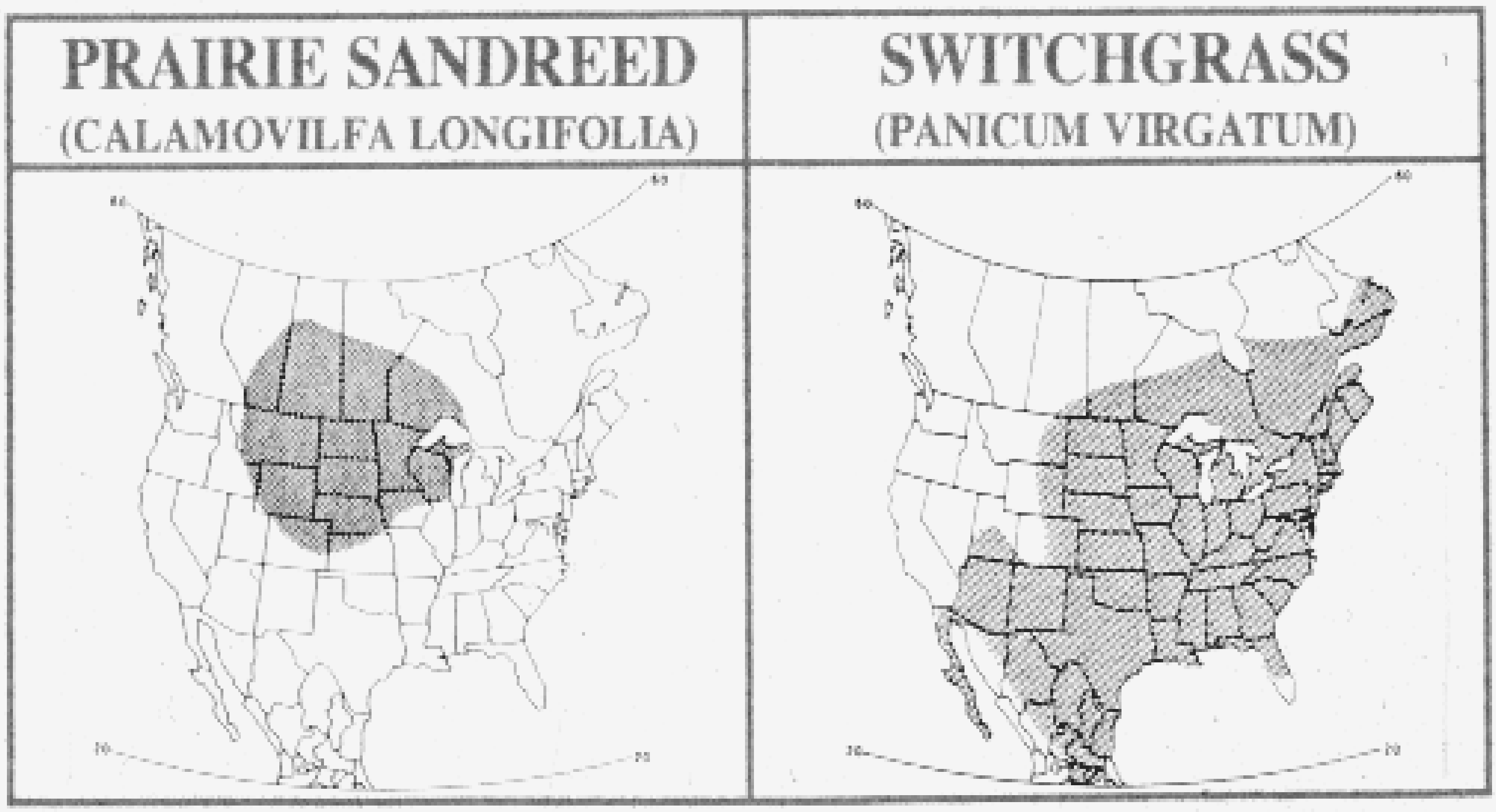
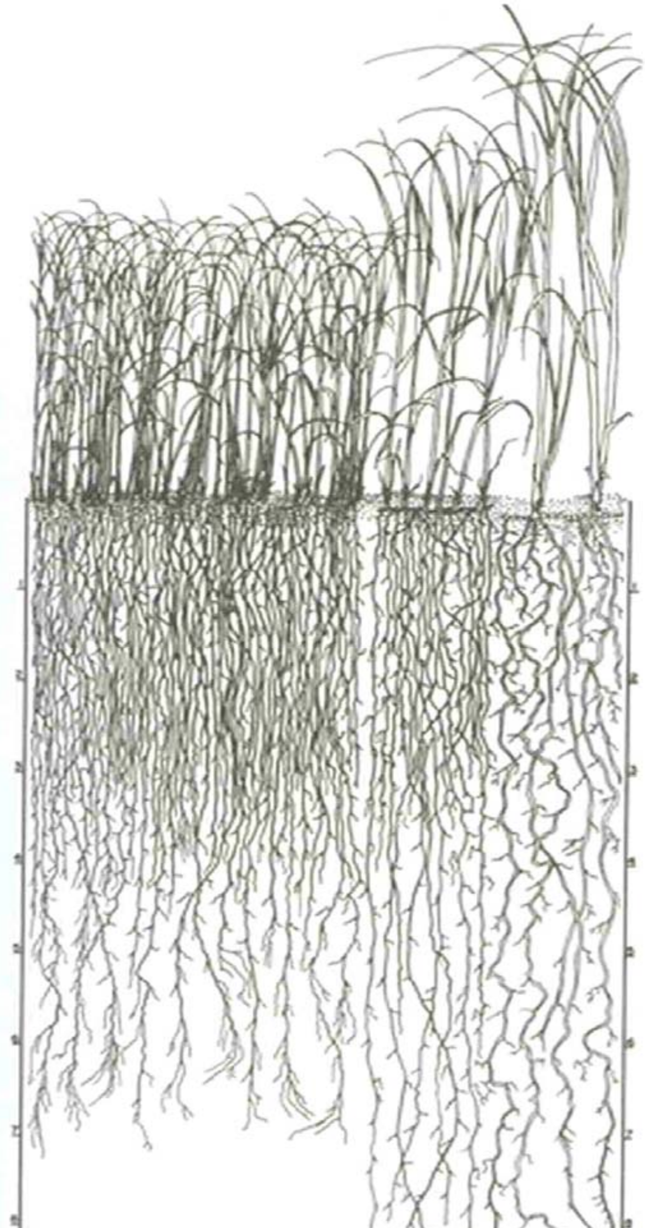
Switchgrass: a multi-use biomass crop



- Biofuel pellets and briquettes
- Biogas (CHP)
- Cellulosic ethanol
- Livestock bedding
- Paper
- “Straw bale” Housing

Native Range of Promising Warm Season Grass Biomass Feedstocks

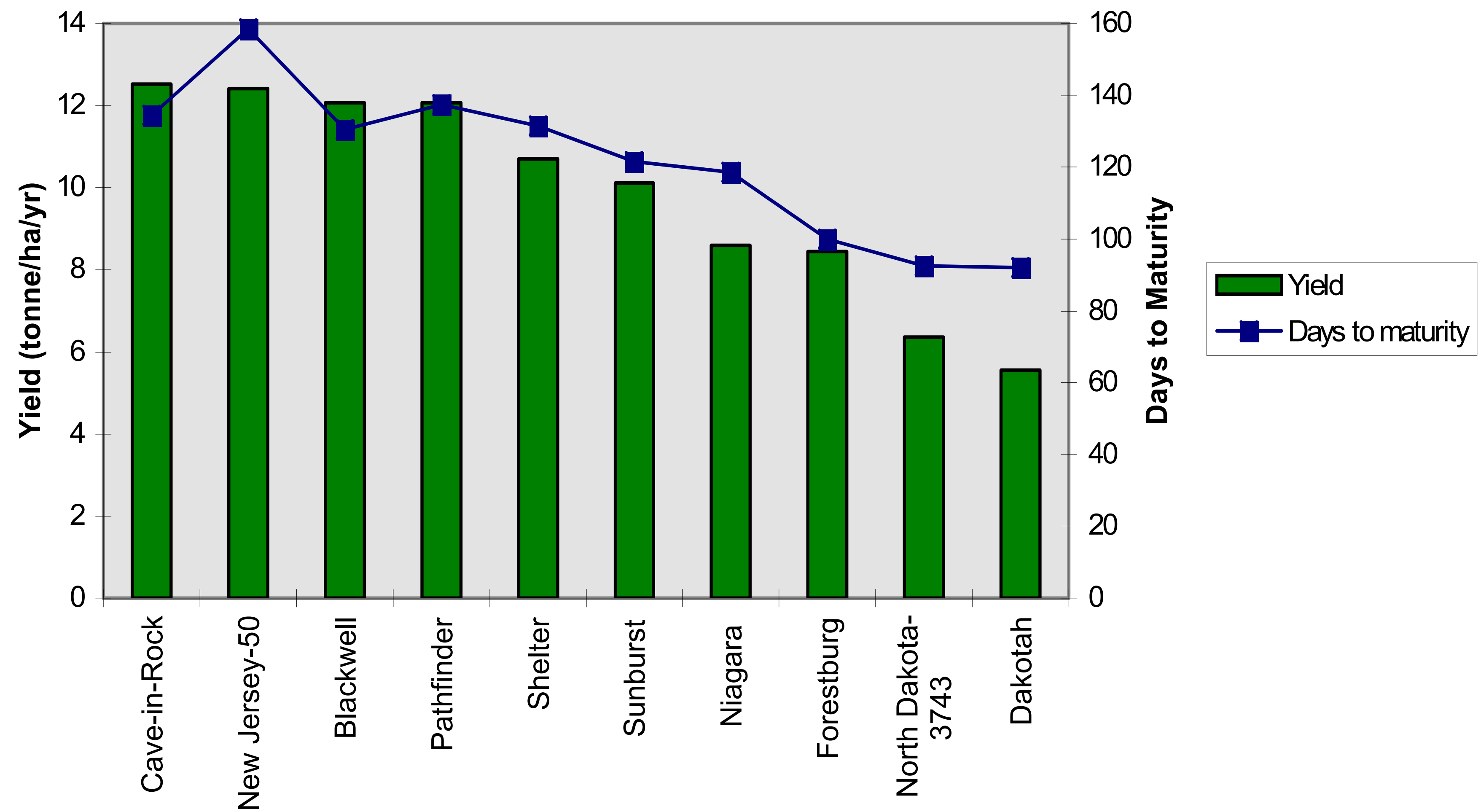





Big Bluestem
in New York


Coastal Panic Grass in
Pennsylvania

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



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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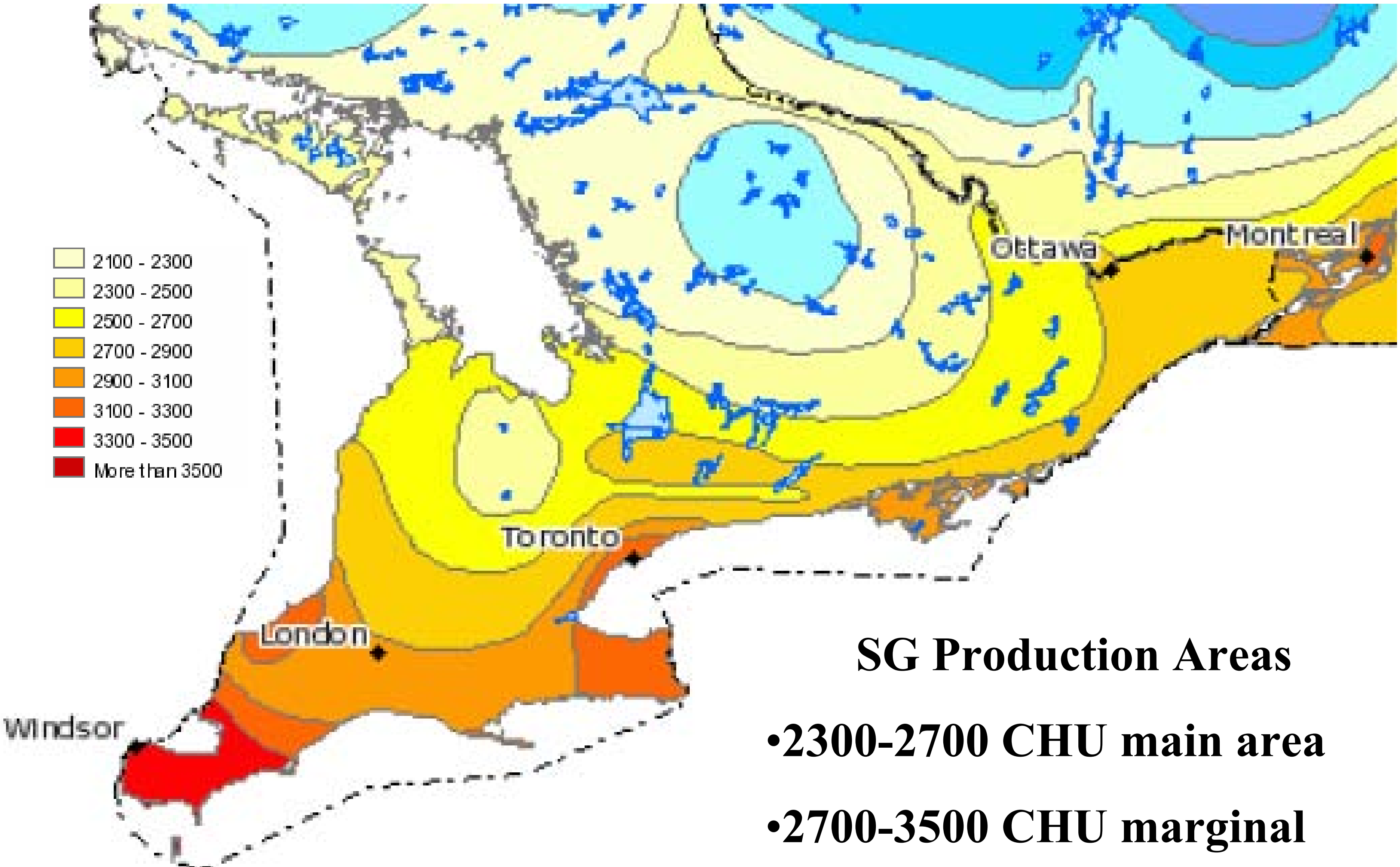
Identifying a Land Base



SG Production Areas

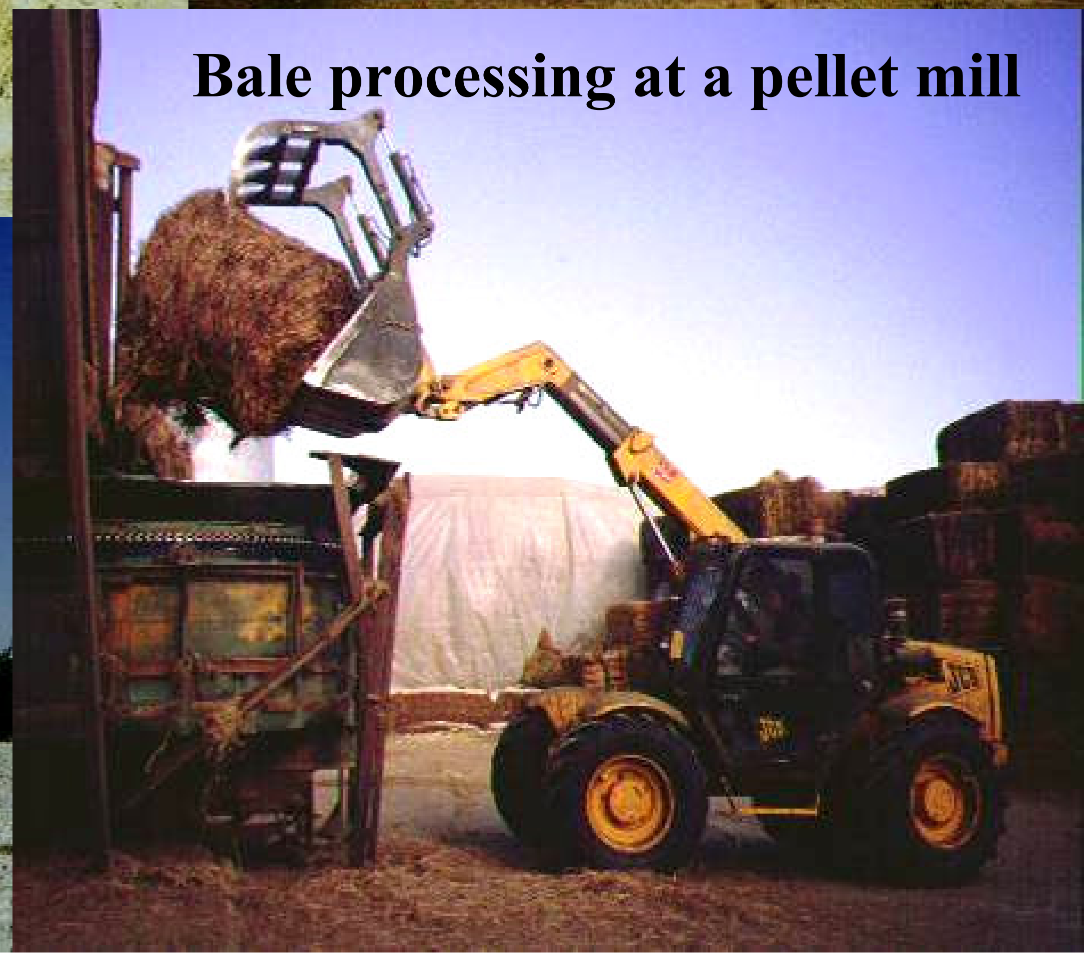
- **2300-2700 CHU main area**
- **2700-3500 CHU marginal lands**

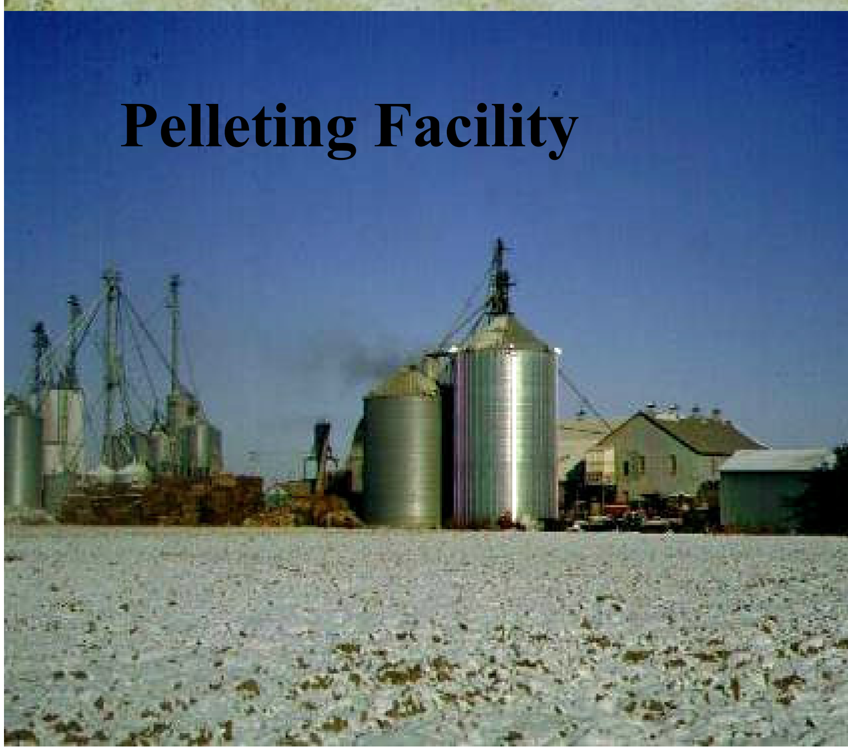
Switchgrass Management

- 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


Switchgrass Harvesting
Operations

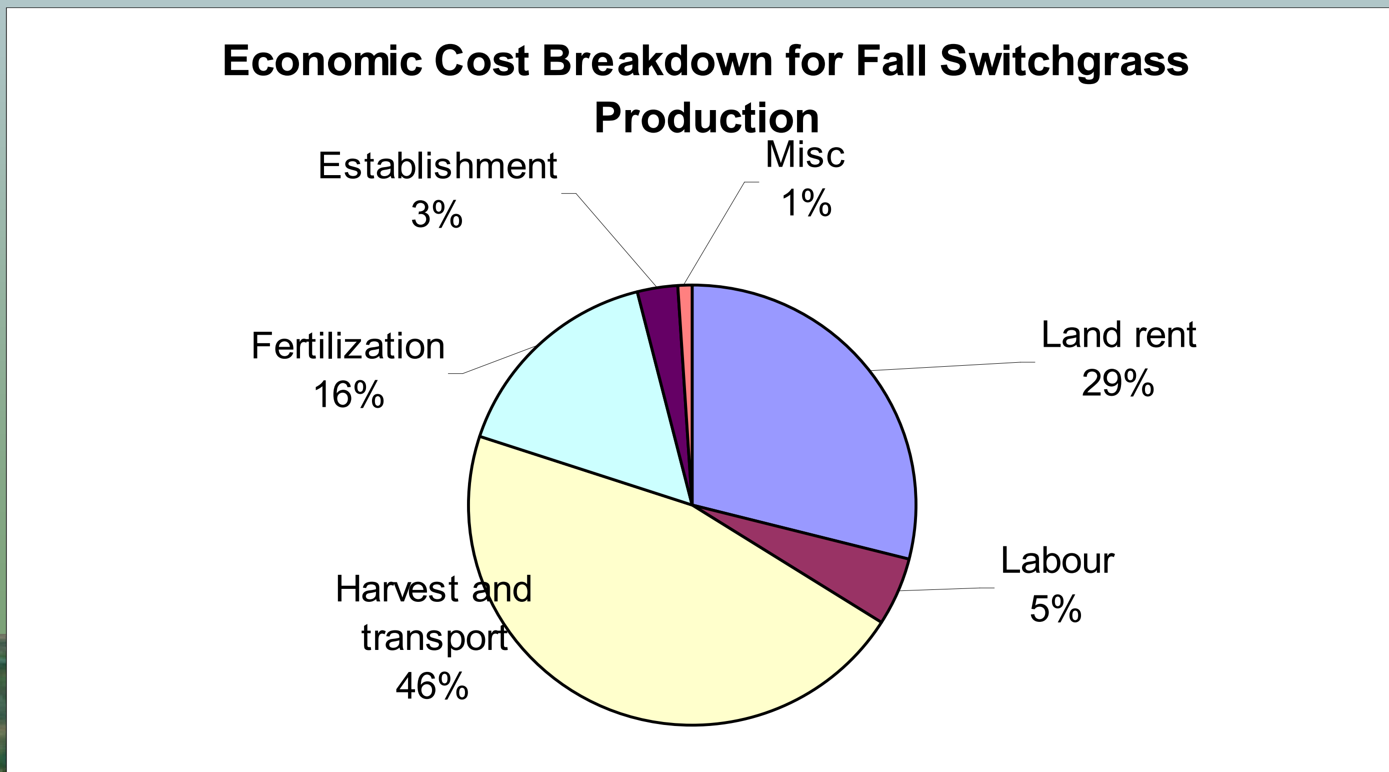

Bale Transport


Bale processing at a pellet mill


Pelleting Facility

Economics of Switchgrass Production in Eastern Canada

- Spring harvesting $61-81CDN/tonne



Producing Rural Energy in Eastern Canada at $ 7/GJ

- Energy grasses grown for $85/tonne or $4.75/GJ
- Densification at $40/tonne or $2.25/GJ
- On-farm fuel at $125/tonne or $7.00/GJ

Incentives will be needed to help market development versus coal and natural gas

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
$263/GJ
→ **$500 million USD capital investment, producing 90 million L/yr**

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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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Options for Densification of Herbaceous Biomass

Biomass → Chopping → Drying (If necessary)

Drying (If necessary) → Grinding → Pelleting

Drying (If necessary) → Briquetting & Cubing

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

Dekker Brand boilers

3 x 800 kw heating a 1.5ha greenhouse


220 KW
Pelco Boiler
heating a 30,000
sq foot building
TOP Pelco TOP
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Grovewood Heat Boiler

75 KW heating a farm complex

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9kw Dellpoint Gasifier Pellet Stove

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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

Fall Switchgrass Harvest

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Harvesting Lessons Learned

- Late fall harvesting (October 25-November 15) and mid winter harvesting appear practical options in Southern Ontario and SW Quebec
- Overwintering losses (~25%) is mainly due to field breakage of vulnerable components (biomass losses are 80% seed heads, 30% leaves, 12% leaf sheaths and 4% stems).
- A new fall mow and spring harvest system appears highly promising to minimize overwintering losses and ease harvest concerns

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

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
- Can we reduce silica transport into WSG’s through plant breeding?
- Can we fractionate WSG’s and send stems to residential pellet markets and higher ash plant components to commercial/industrial pellet markets?

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

Potential for Bioenergy Production

Land use	Agricultural Land (million ha)	Area for biofuel production* (million ha)	Perennial grass production** (million tonnes)	Millions Barrels of Oil Equivalent (MBOE)/day
Canada	68	13.6	80.2	.69
U.S.A.	377	75.4	610.7	5.23
North America	**445**	**89**	**691**	**5.92**

The grass farmers of North America can produce the energy equivalent of 7.2% of the worlds oil supply (82 million barrels of oil/day)

*** Estimated 20% 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**

Biofuel GHG Offsets Basics

GHG offsets are a function of 2 main factors:

The total amount of renewable energy (GJ) produced/ha
(solar energy collected in the field less energy lost going through the biofuel conversion process)

→

The amount of fossil energy (GJ) used in the production of the feedstock/ha

The amount of fossil energy used to convert the raw feedstock to a processed biofuel form

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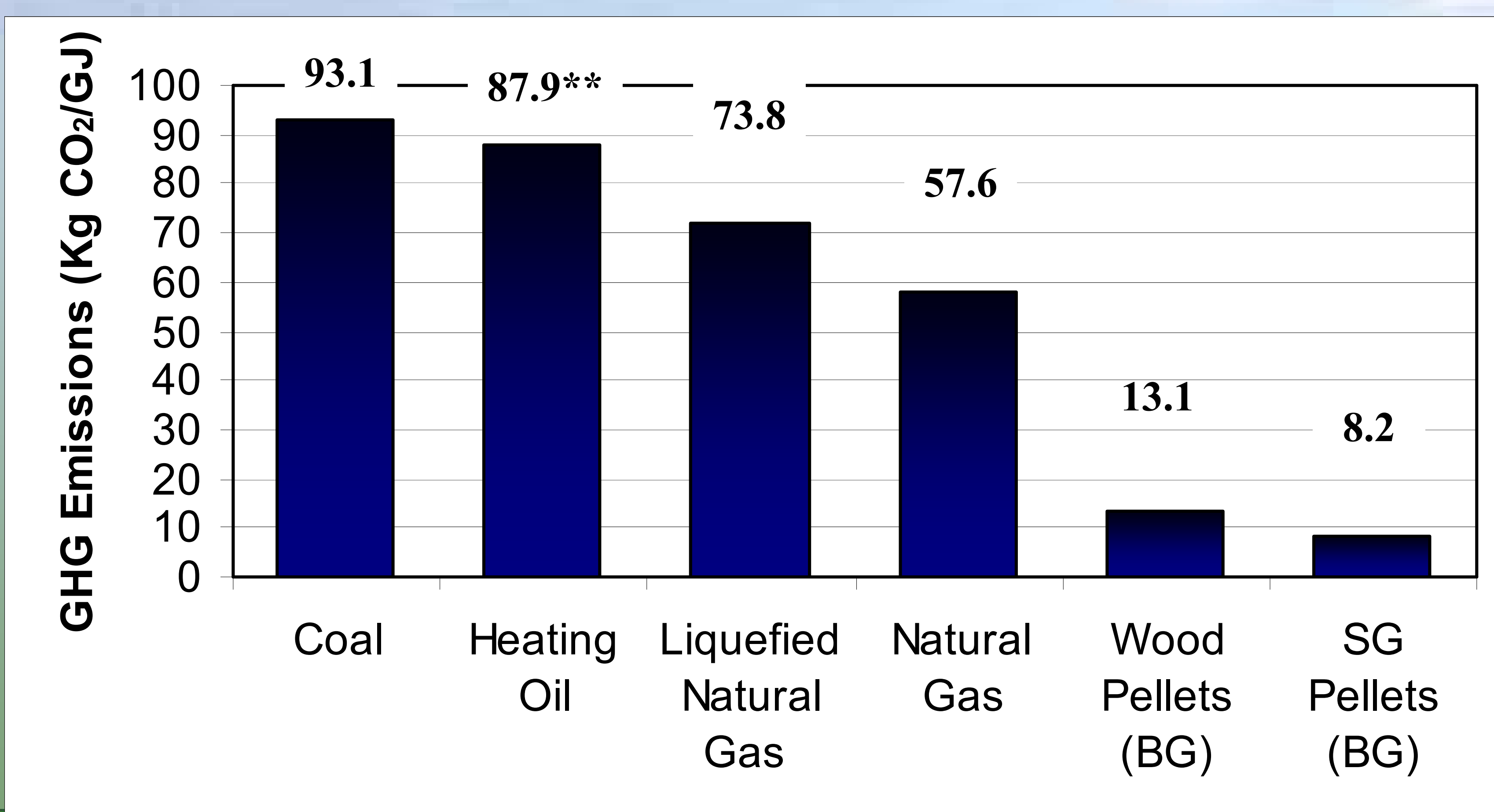
Relative Carbon Intensity of Various Fuel Sources



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*Based on GHGenius 3.9xls Natural Resources Canada, Samson et al., 2008

**Based on typical Canadian oil mix of 48% domestic and 52% international

Comparing Biofuels as Offset Strategies

Factors to Consider:

- Net GHG savings by replacing a fossil fuel with a a biofuel option (kg CO_2e/GJ).
- Efficiency of the offset (%).
- The cost of incentives or subsidies for each unit energy produced ($/GJ).
- Cost required to offset 1 tonne of CO_2e ($/tonne).

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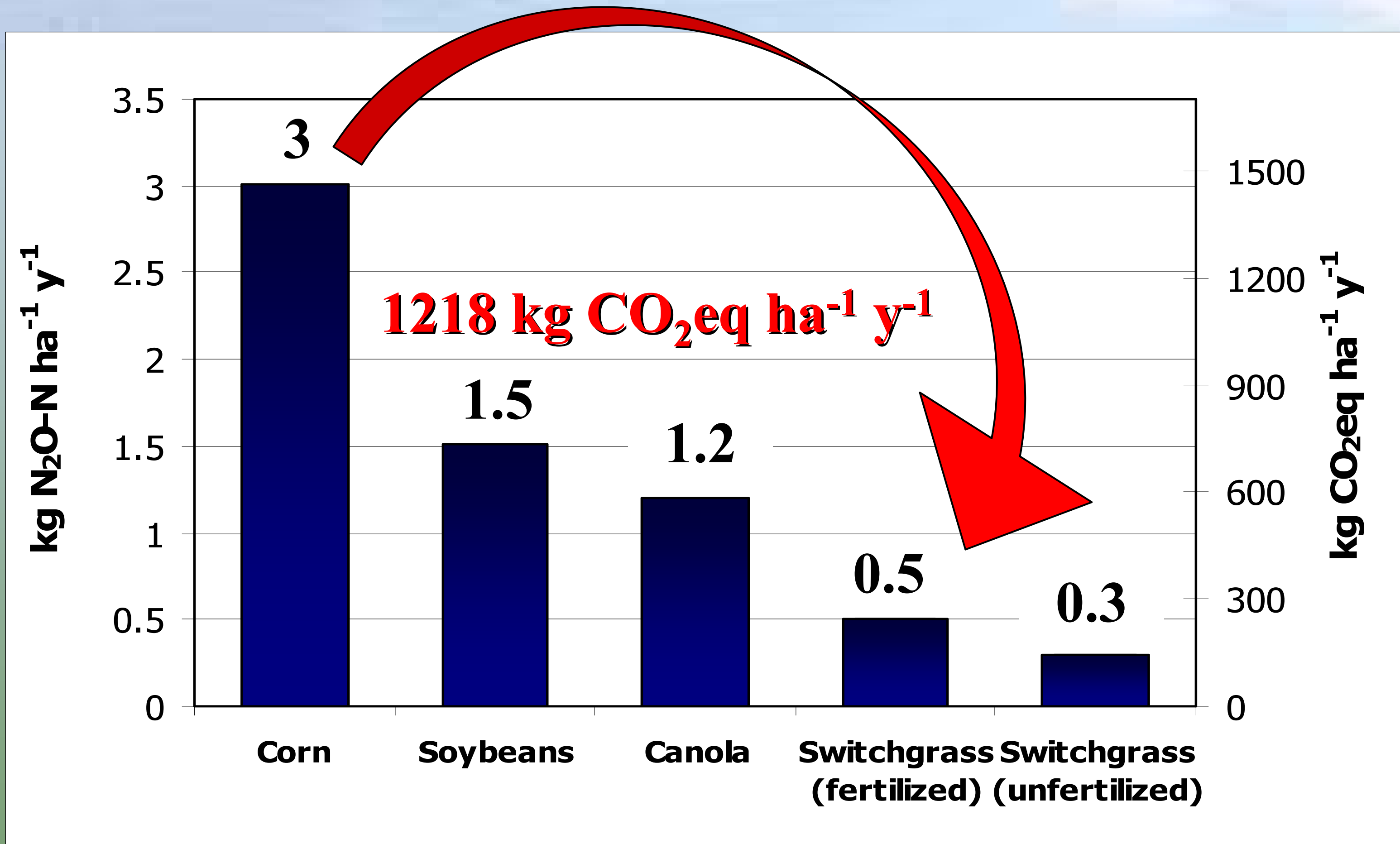
N_2O Emissions from Crop Production in Canada



e.g. Corn: 3 kg N_2O-N x 44/28 x 310 (CO_2 forcing value for N_2O) = 1461 kg CO2eq/ha

Samson et al 2007

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Biofuel Options Examined

Sector	Traditional Fuel		Alternative Fuel
Transportation	Gasoline	→	Ethanol
	Diesel	→	Biodiesel
Electrical Power	Coal Natural gas	→	Wind energy Straw pellets Biogas
Heating	Coal Natural gas LNG	→	Switchgrass/Wood pellets

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LNG-liquefied natural gas

Transportation Sector-GHG Offsets

Fossil Fuel		Renewable Fuel		Net offset (%)
	kg CO_2e/GJ		kg CO_2e/GJ	
Gasoline	99.6	Corn ethanol	62.0	21
		Cellulosic ethanol	23.4*	76
Diesel	95.5	Soybean biodiesel	36.4	50
		Canola biodiesel	28.8	58

* Does not include GHG emissions associated with N_2O from cultivation

Samson et al., 2007

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Electrical Power-GHG Offsets

Fossil Fuel		Renewable Fuel		Net offset (%)
	kg CO_2e/GJ		kg CO_2e/GJ	
Coal	298.9	Wind	5.6	98
		Straw Pellets	18.9	94
		Biopower (manure)*	39.4	87
Natural gas	121.7	Wind	5.6	95
		Straw Pellets	18.9	84
		Biopower (manure)*	39.4	68

•Does not include GHG emission reductions from manure through biogas treatment

Samson et al., 2007

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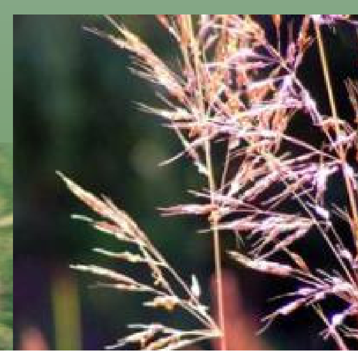
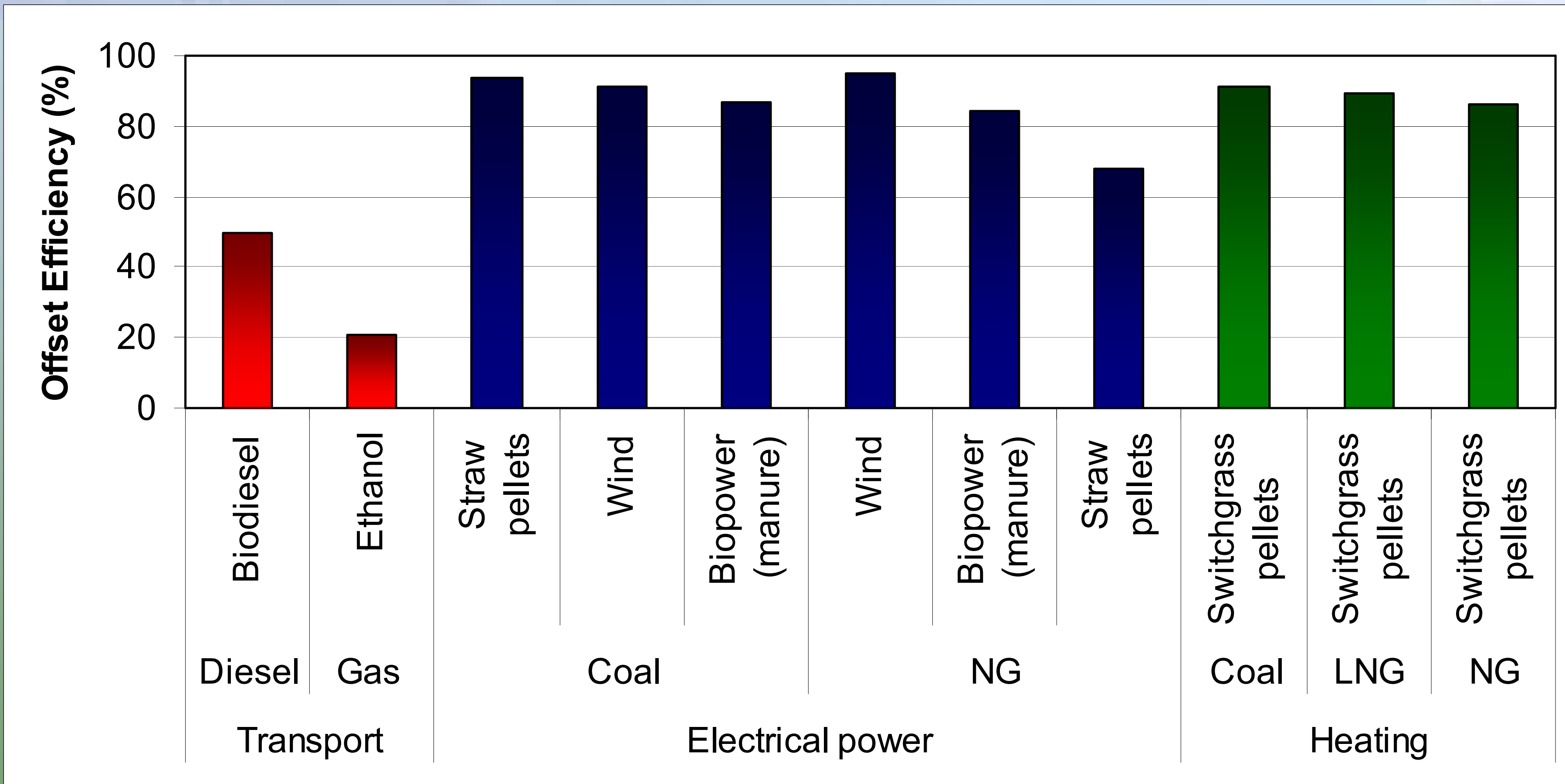
Heat Generation-GHG Offsets

Fossil Fuel		Renewable Fuel		Net offset (%)
	kg CO_2e/GJ		kg CO_2e/GJ	
Coal	93.1	Switchgrass pellets	8.2	91
LNG	87.9	Switchgrass pellets	8.2	89
Natural gas	57.6	Switchgrass pellets	8.2	86

Samson et al., 2007



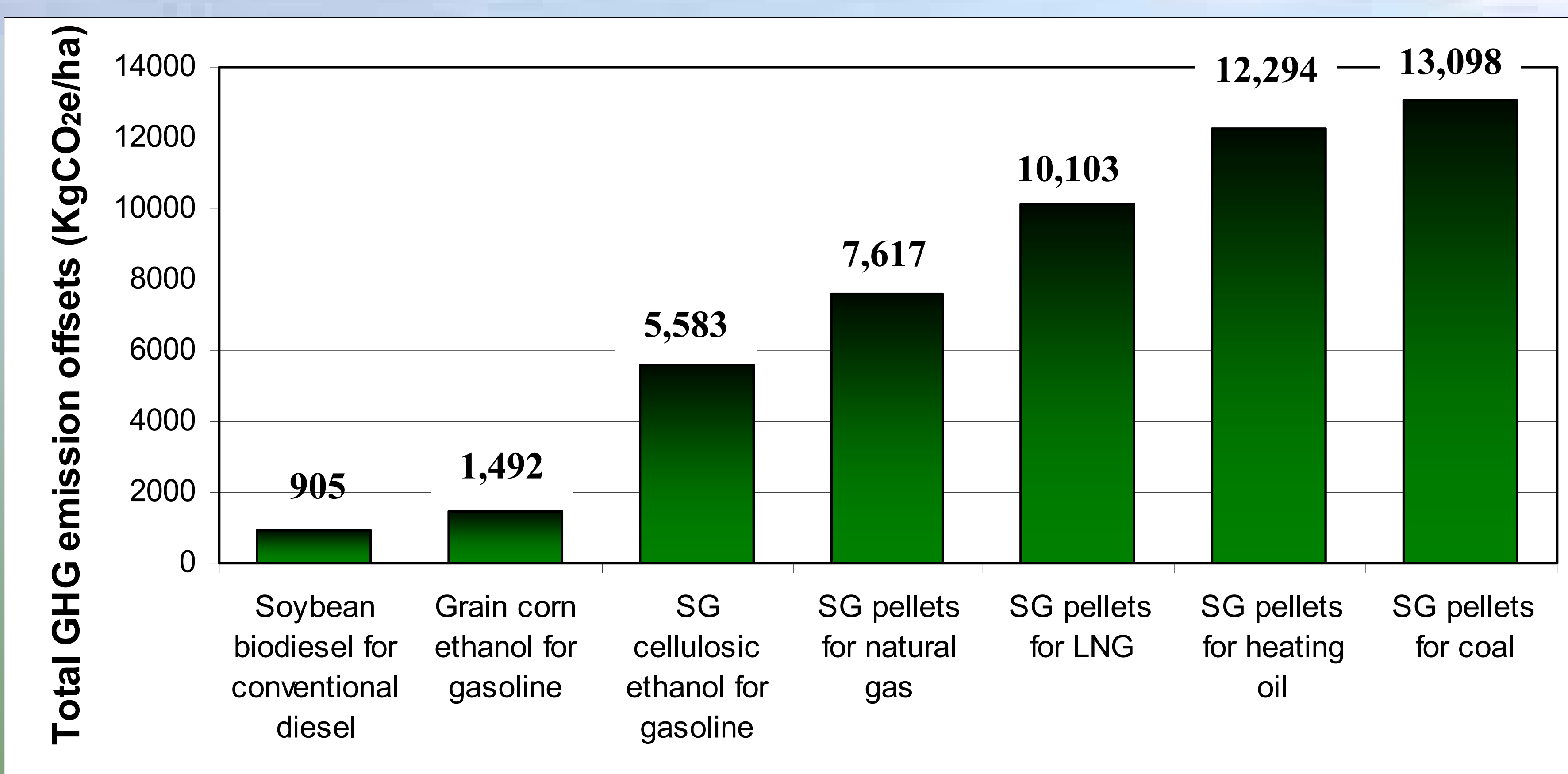
Offset Efficiency of Biofuel Options



NG-natural gas; LNG-liquefied natural gas

Samson et al. 2007

GHG Offsets From Ontario Farmland Using Biofuels



SG=Switchgrass; LNG=Liquefied Natural Gas

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Summary

- Biofuel GHG offsets are directly linked to
  - Offset efficiency of the biofuel (GJ)
  - Energy produced (GJ) per ha of biofuel crop

Biofuel Option	Offset efficiency	Output (GJ/ha)	Overall efficiency
Switchgrass pellets	High	High	↑
Switchgrass ethanol	Moderate to high	Moderate	
Corn ethanol	Low	Moderate	
Soybean biodiesel	Moderate	Low	

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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

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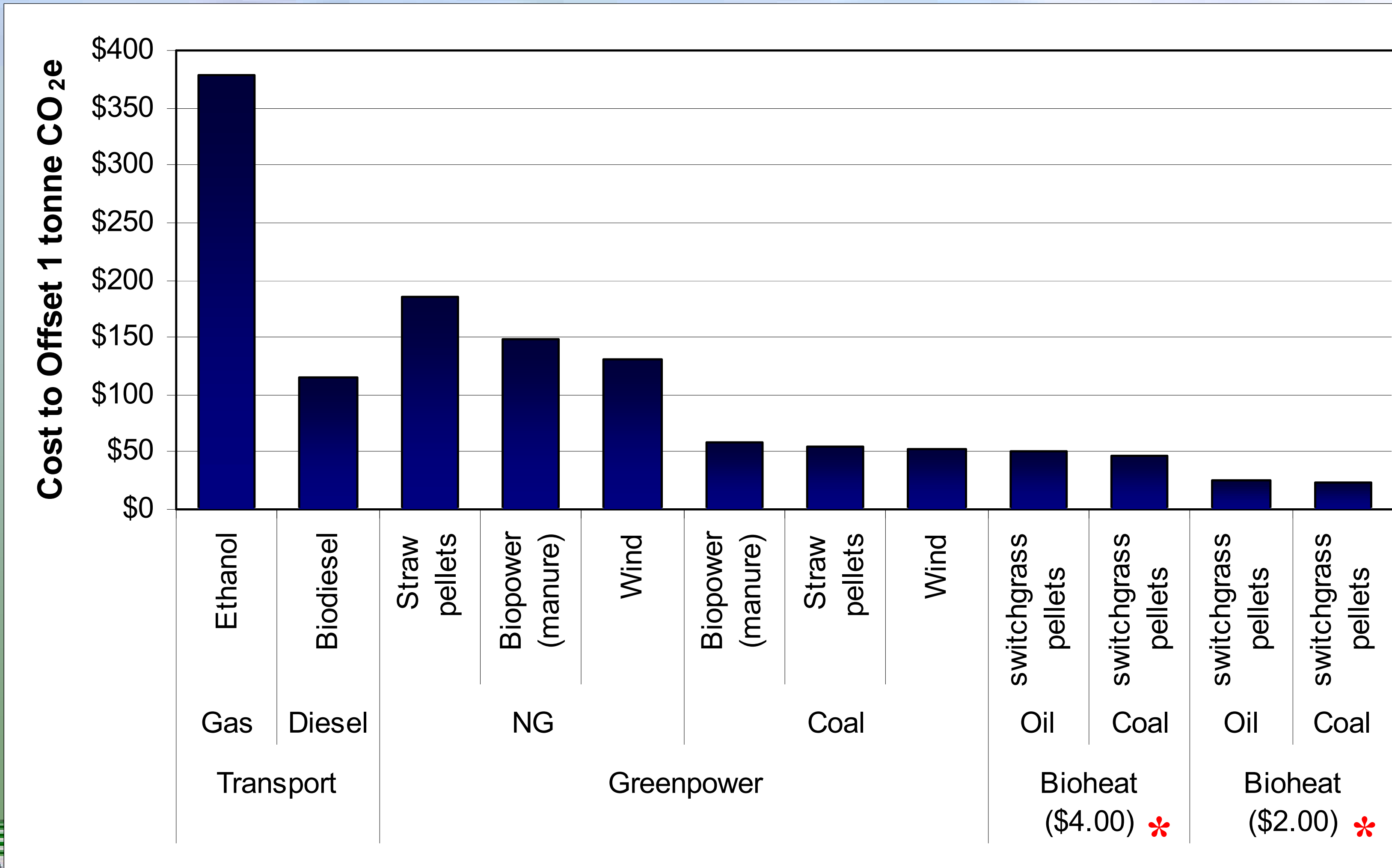
Costs required to offset 1 tonne CO_2e with current Ont. & Federal Incentives



*Suggested incentive

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Samson et al. 2008

Policy Instrument Options:

to enable efficient bioenergy and renewable energy technologies

- Apply incentives by GJ of renewable fuel produced:
  - $8/GJ for liquid fuel
  - $15/GJ green power
  - $4/GJ green heat
- Best solution might be:
  - $25/tonne CO_{2eq} carbon tax
  - $25/tonne CO_{2eq} renewable carbon incentives paid to biofuel producers

Summary and Conclusions

- Warm season grasses represent the most resource efficient way to capture solar energy through crop production
- WSG biomass quality for combustion can be improved through cultural management and breeding
- Biggest emerging application is thermal energy to replace coal, natural gas and LNG

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Summary (Continued)

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

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