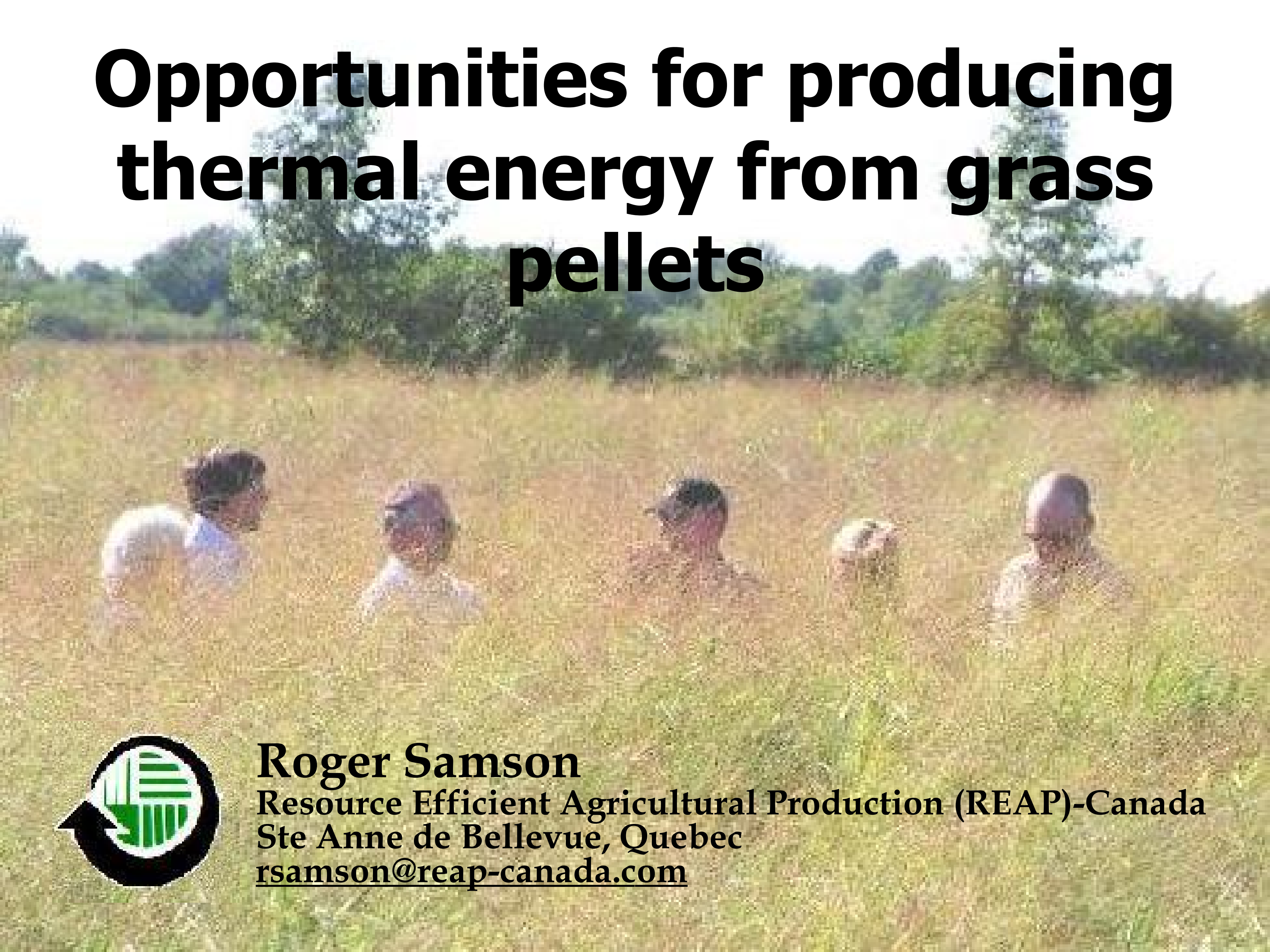

Opportunities for producing thermal energy from grass pellets

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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 and the climate change problem
- One of the greatest challenges of humanity is to create resource efficient bioenergy systems from our agricultural lands

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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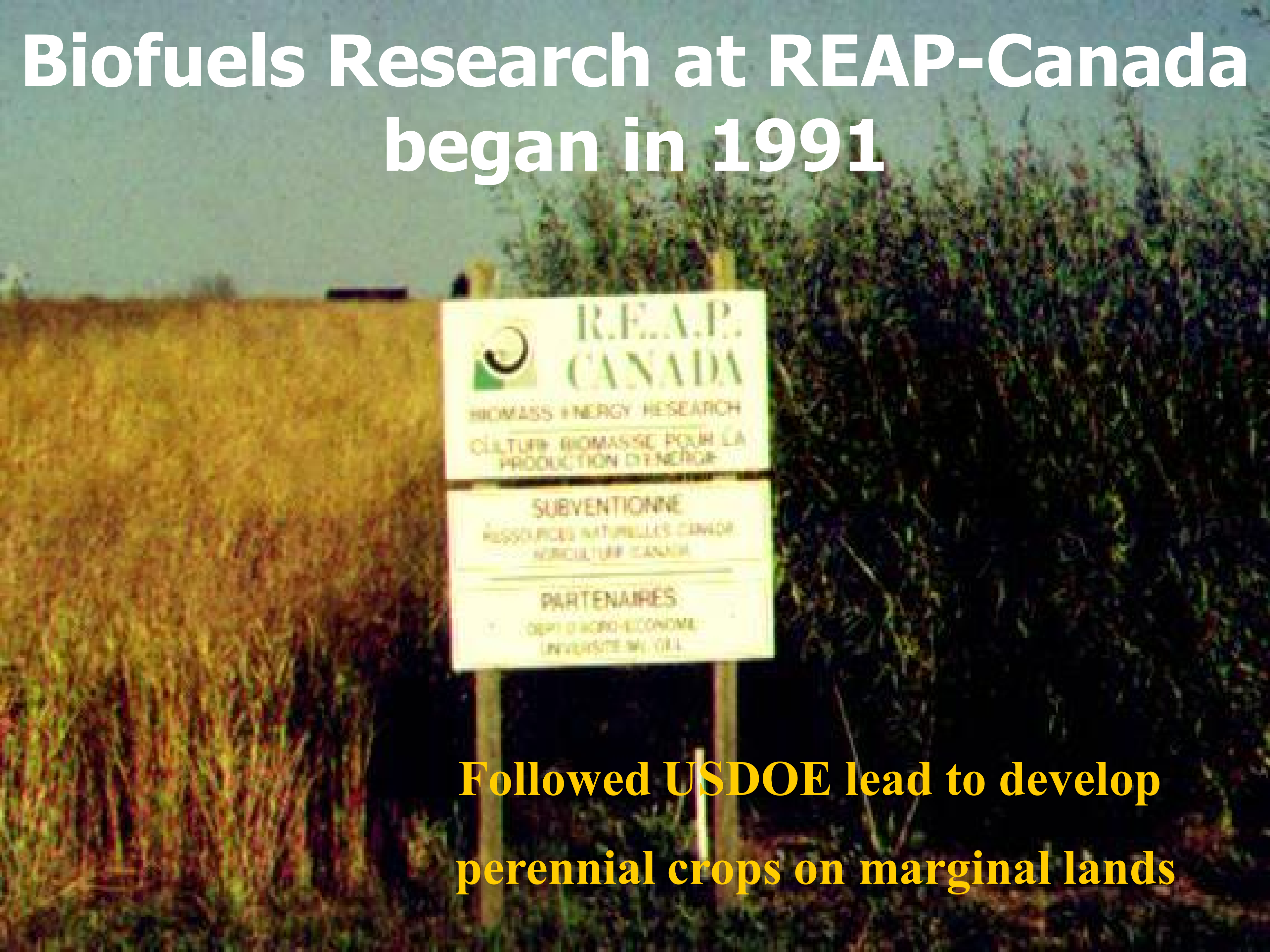
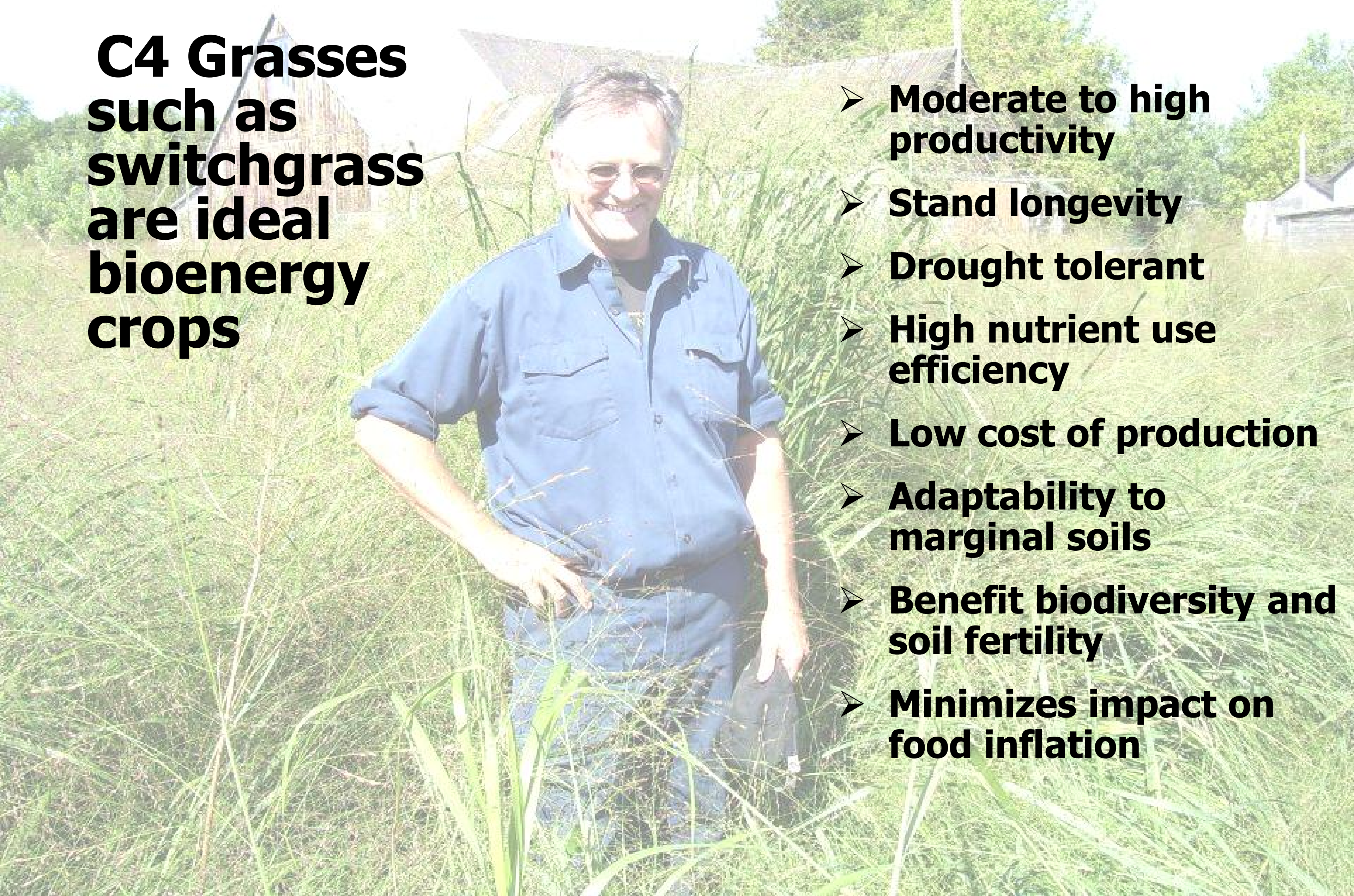
Biofuels Research at REAP-Canada began in 1991



Followed USDOE lead to develop perennial crops on marginal lands

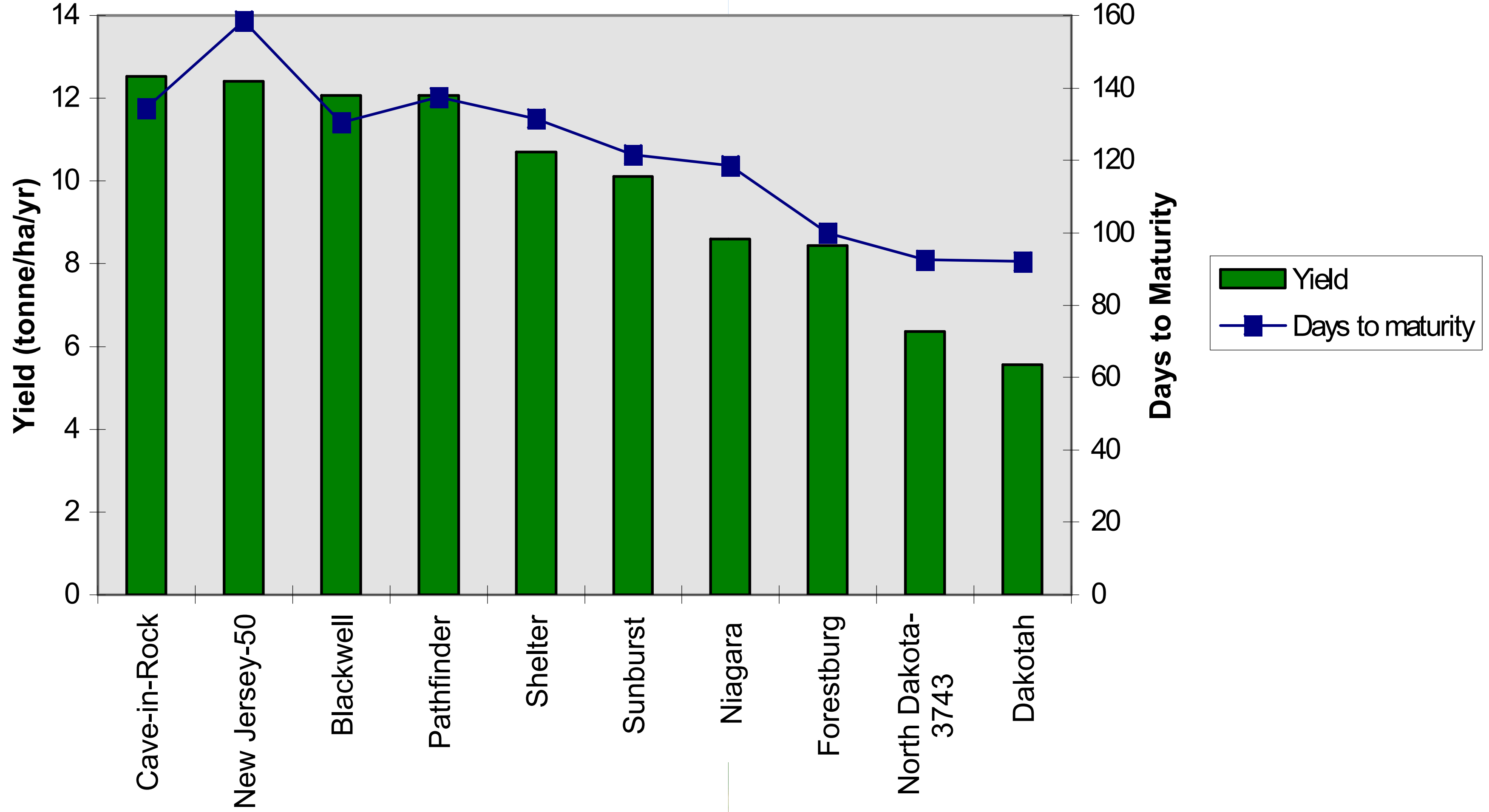
Warm Season Grasses



C4 Grasses such as switchgrass are ideal bioenergy crops

- Moderate to high productivity
- Stand longevity
- Drought tolerant
- High nutrient use efficiency
- Low cost of production
- Adaptability to marginal soils
- Benefit biodiversity and soil fertility
- Minimizes impact on food inflation

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



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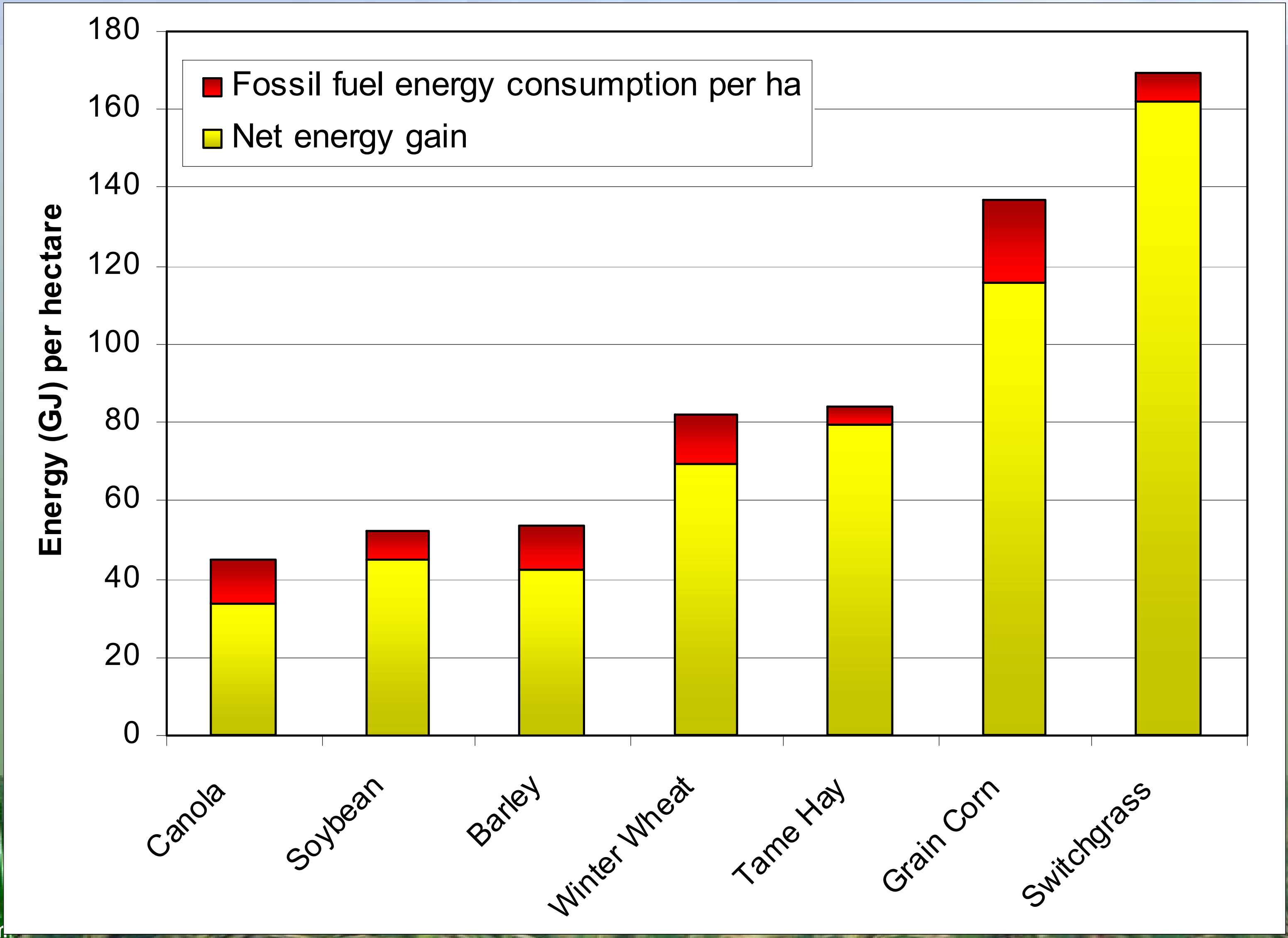
Solar Energy Capture and Net Energy Gain of Ontario Field Crops (Samson et al., 2008)



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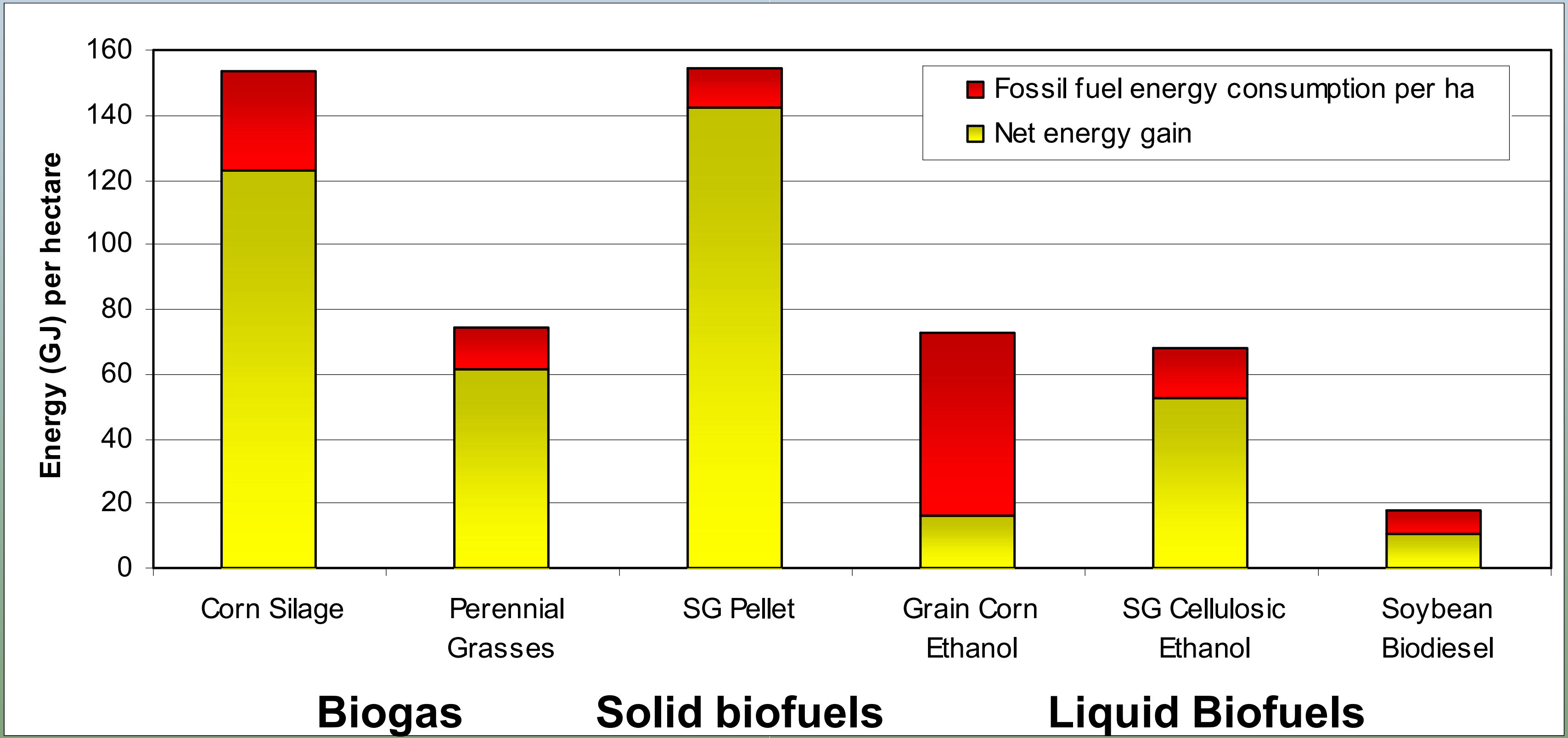
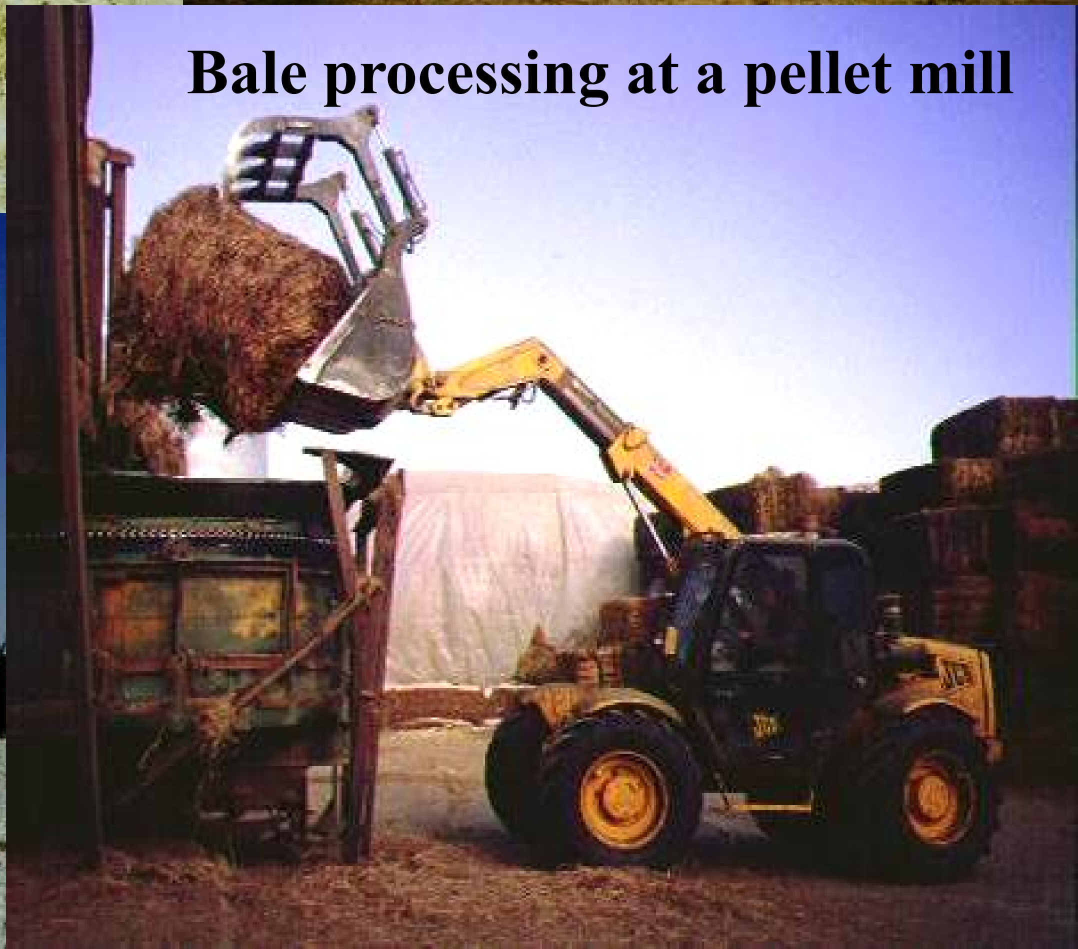
Assessment of Net Energy Gain from Ontario Farmland using various Biomass and Bioconversion Options (Samson et al., 2008)



SG=Switchgrass


Switchgrass Harvesting Operations


Bale Transport


Bale processing at a pellet mill


Pelleting Facility

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

Bioenergy Capital Costs Investment Requirements

($ per GJ Output Energy plant)

Grass Pellet
$5/GJ

→ **$6 million USD capital investment, producing 60,000 tonnes/yr**

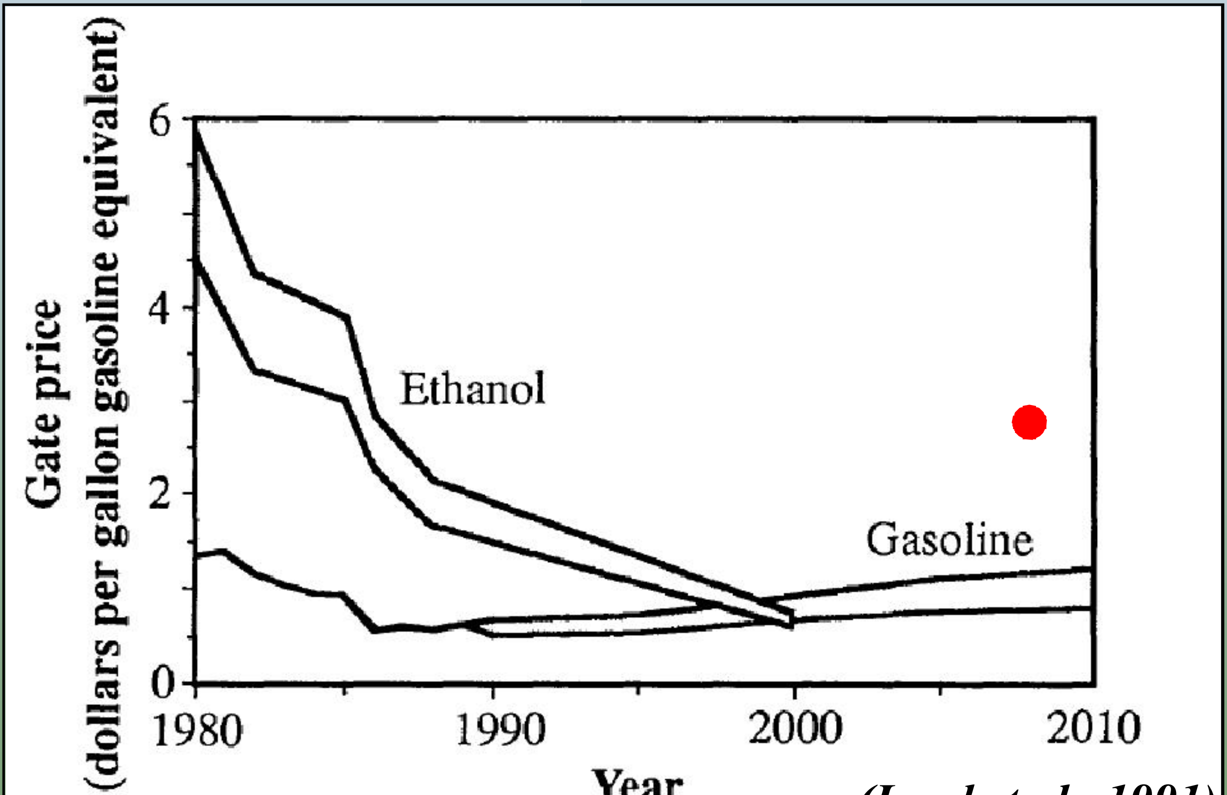
Corn ethanol
$24/GJ

→ **$102 million USD capital investment, producing 200 million L/yr**

Cellulosic ethanol
$263/GJ

→ **$500 million USD capital investment, producing 90 million L/yr (globe and mail, march15, 2008)**

Cellulosic ethanol not acheiving projected cost reductions



(Lynd et al., 1991)

- **Gate or Rack price of gasoline in June 2008: $3.00/Gallon**

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Effect of fall vs spring mow on yield and quality

Fall Mow, Spring Bale:

- *Fall mow took place on November 25th, 2006*
  - 12' disc mower conditioner, cut height of 10.1 cm
- *Spring baling operations took place on May 3, 2007*
  - Raking was performed prior to baling

Spring Mow, Spring Bale:

- *Spring mowing and baling operations took place on May 3rd and 4th, 2007*
  - No raking necessary


FALL
WINTER
SPRING

Machine Harvested Recovered Yields

Treatment	Yield (ODT/ha)	Moisture Content (%)
Fall mow & spring bale	6.574*	6.0
Spring mow & bale	5.443	7.8

*Significantly different ($p<0.05$)

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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

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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

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Ontario greenhouse with multi-fuel coal/pellet boilers (3 x 800 kw)

Biofuel GHG Offsets Basics

GHG offsets are a function of several 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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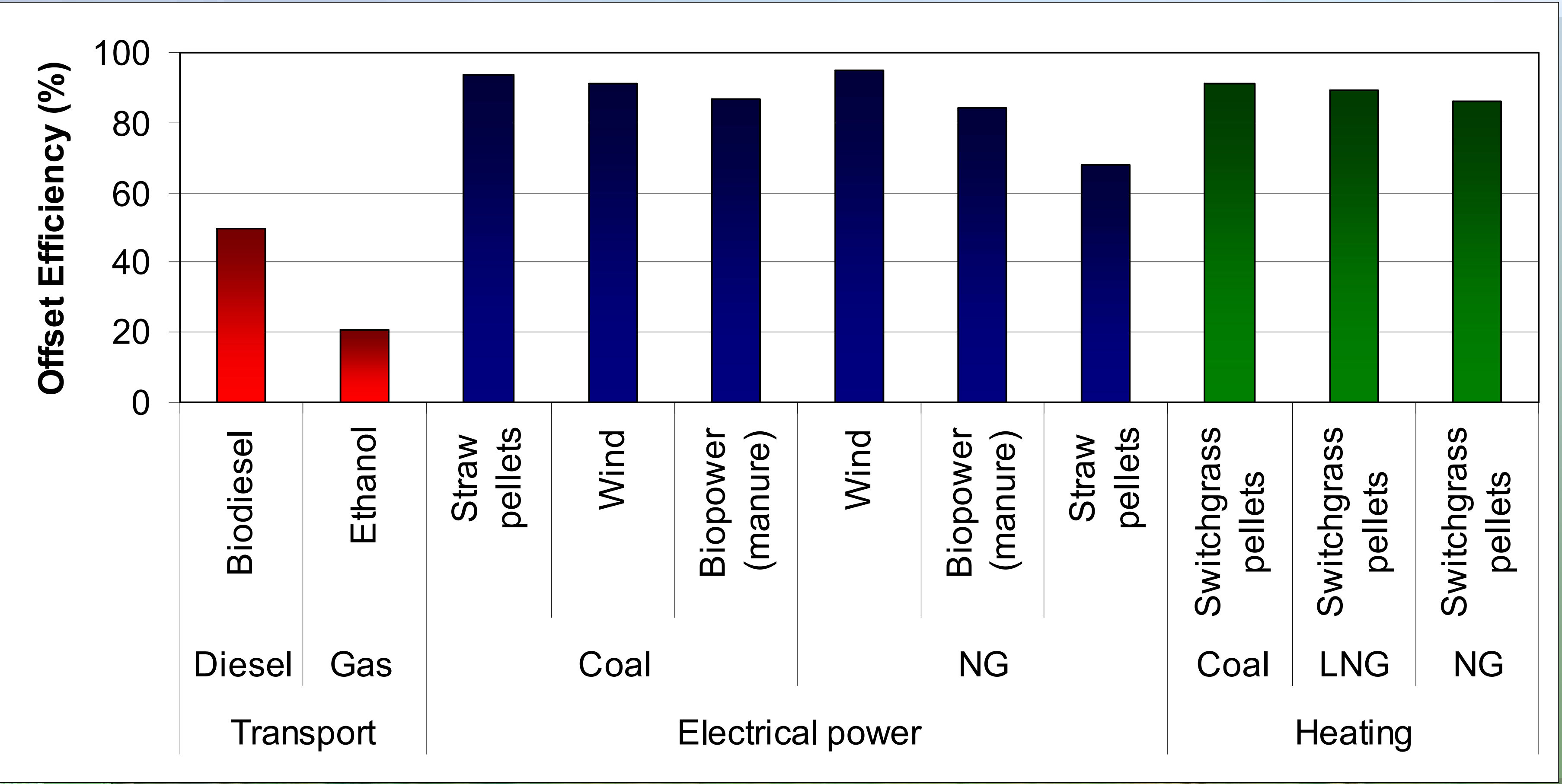
Offset Efficiency of Biofuel Options



NG-natural gas; LNG-liquefied natural gas

Samson et al. 2008

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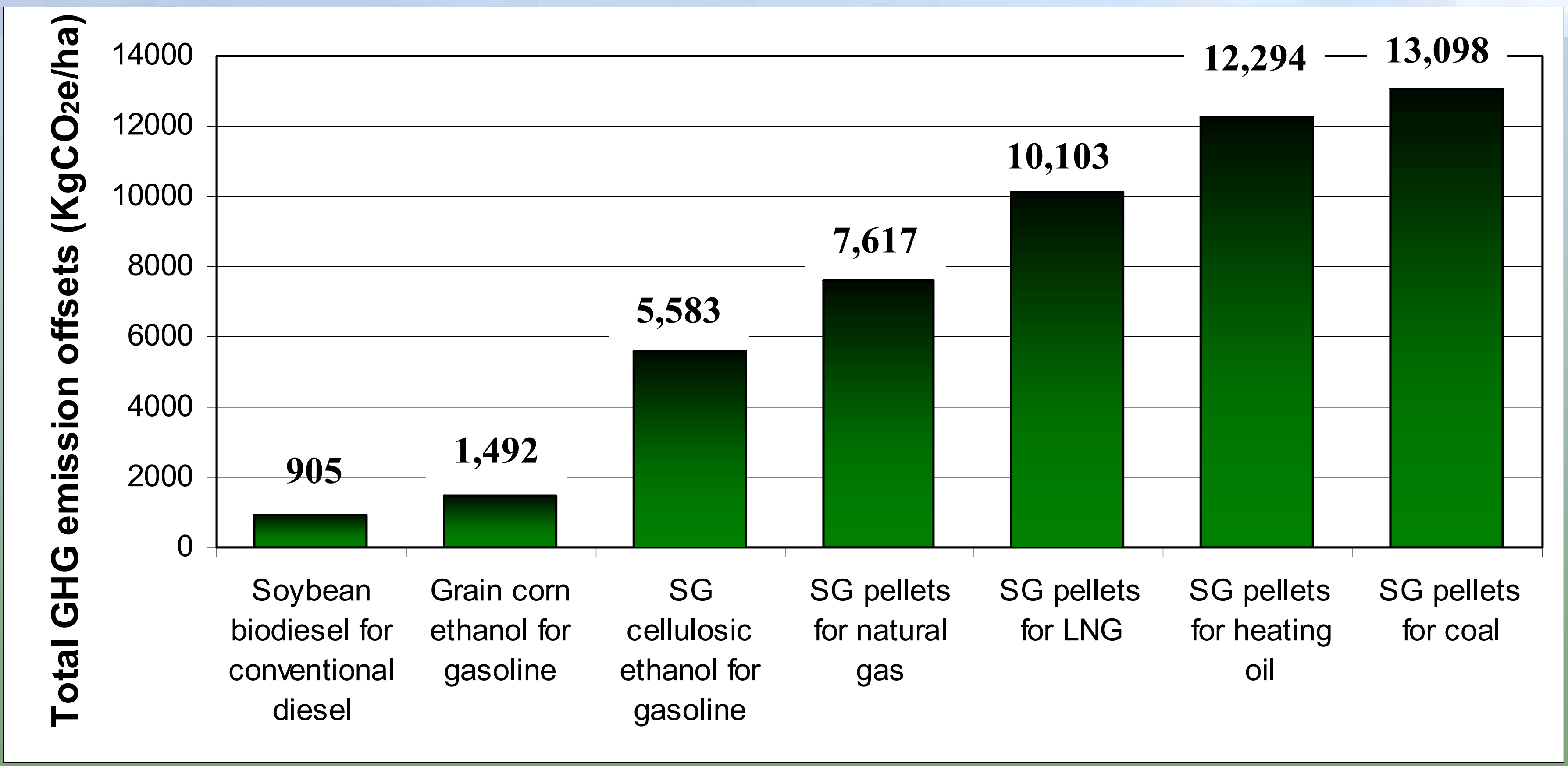
GHG Offsets From Ontario Farmland Using Biofuels (Samson et al 2008)



SG=Switchgrass; LNG=Liquefied Natural Gas

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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

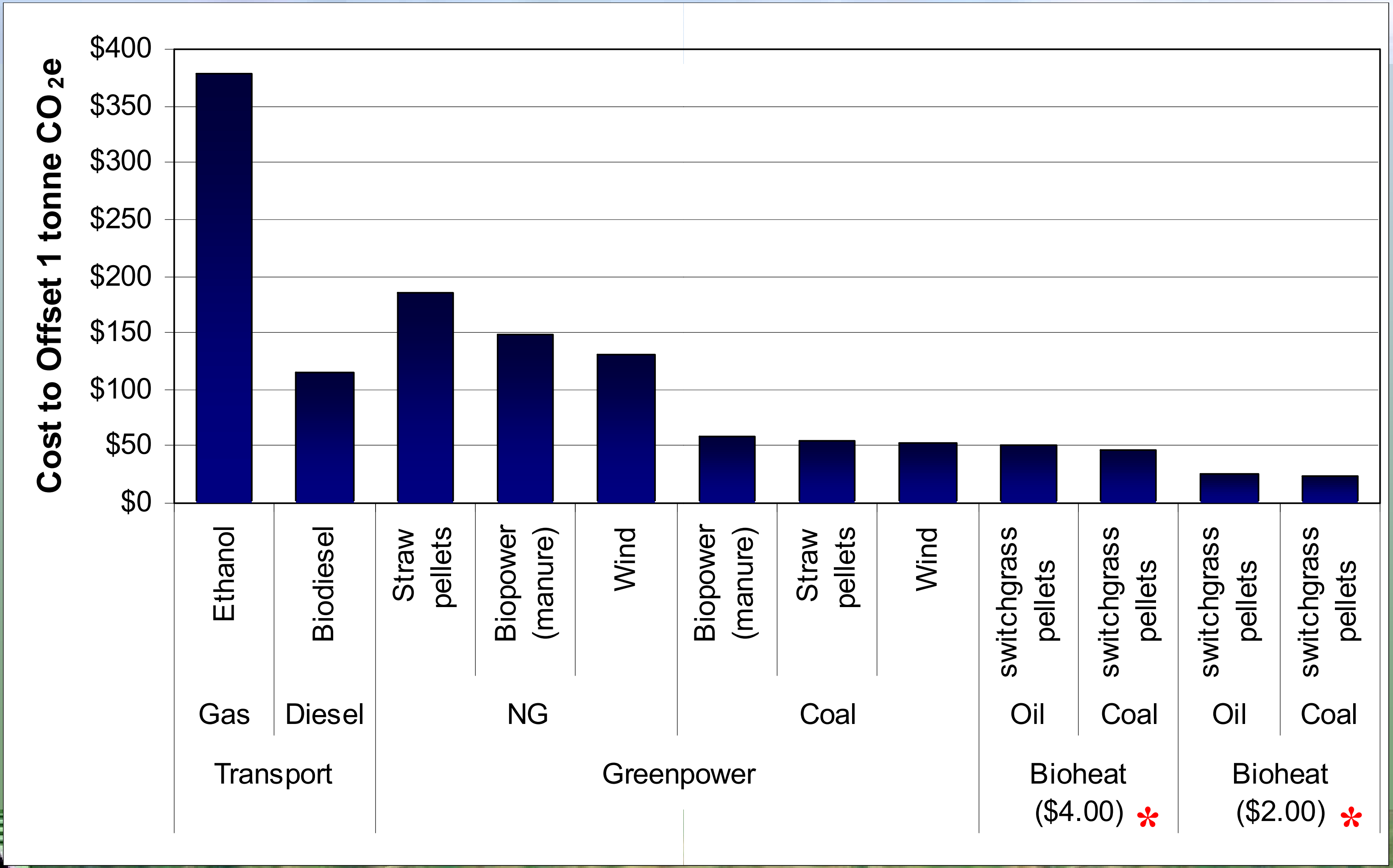
Incentive Assumptions:

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

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



*Suggested incentive

Samson et al. 2008

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Provinces need more progressive RET and climate change policy leadership from the federal government

- 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 and reward technologies that appreciably reduce CO2

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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

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Thank You!

REAP-Canada's Biomass Energy Program Sponsored by

Natural Resources Canada

Canadian Farm Business Management Council

Ontario Ministry of Agriculture, Food and Rural Affairs

Alberta Agriculture and Food

Alberta Research Council

ERNST

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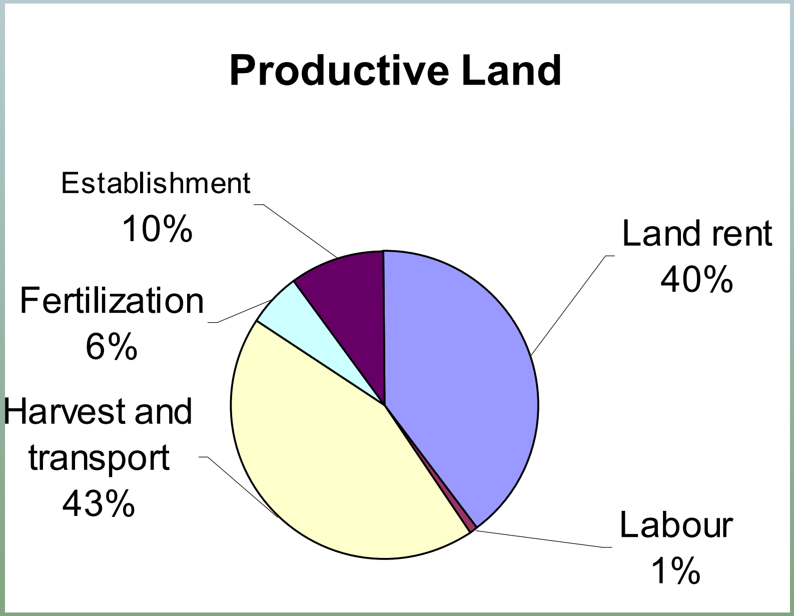
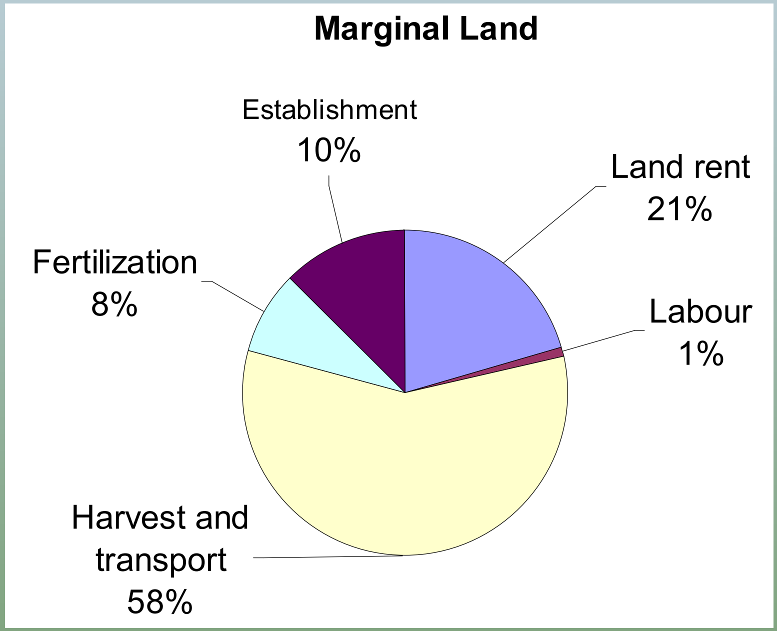
Economics of Switchgrass Production in Eastern Canada

Spring harvesting $61-81 CDN/tonne





Establishment Costs $212.93/ac (not including land rent)

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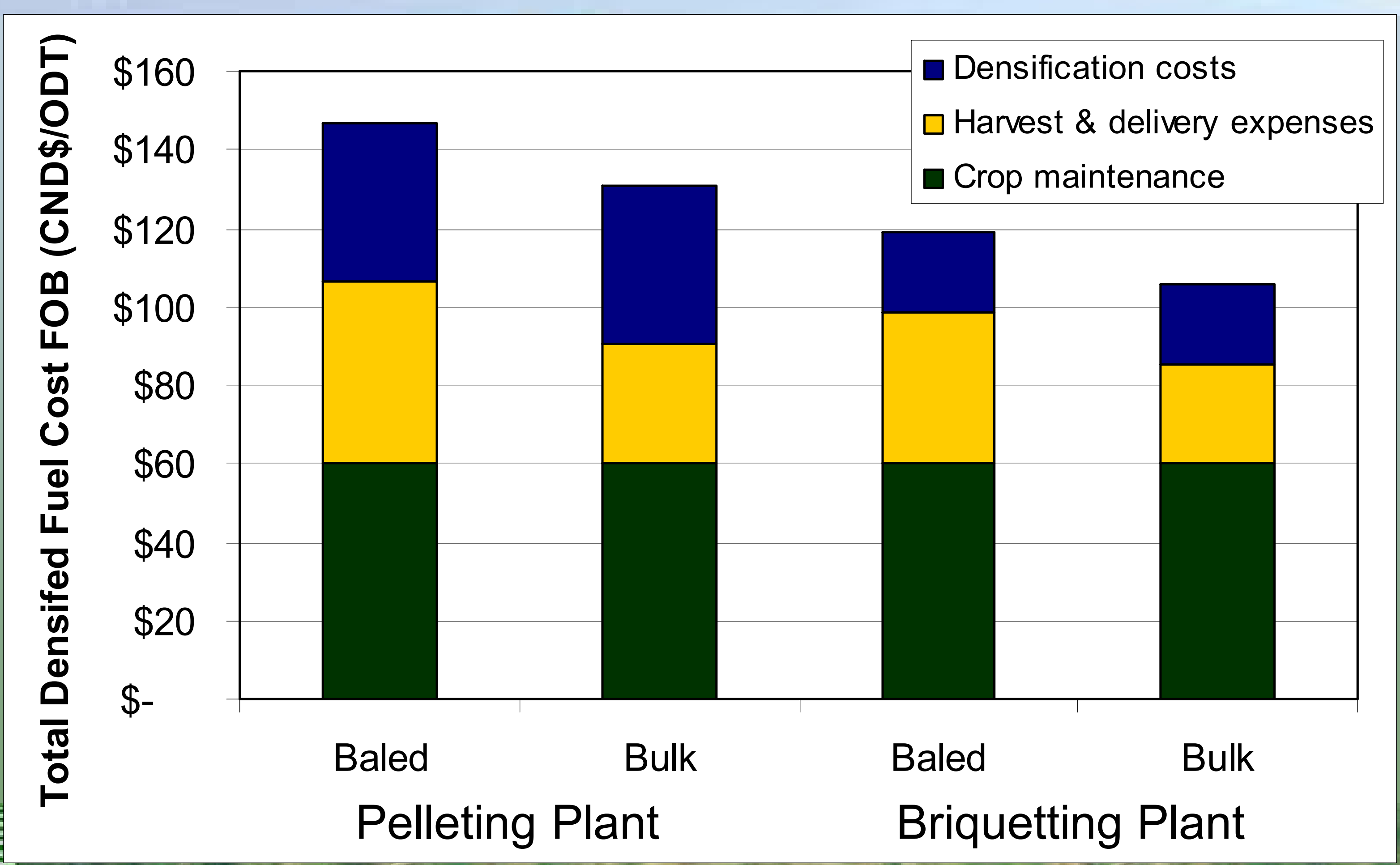
Estimated Densified Fuel Costs in Ontario



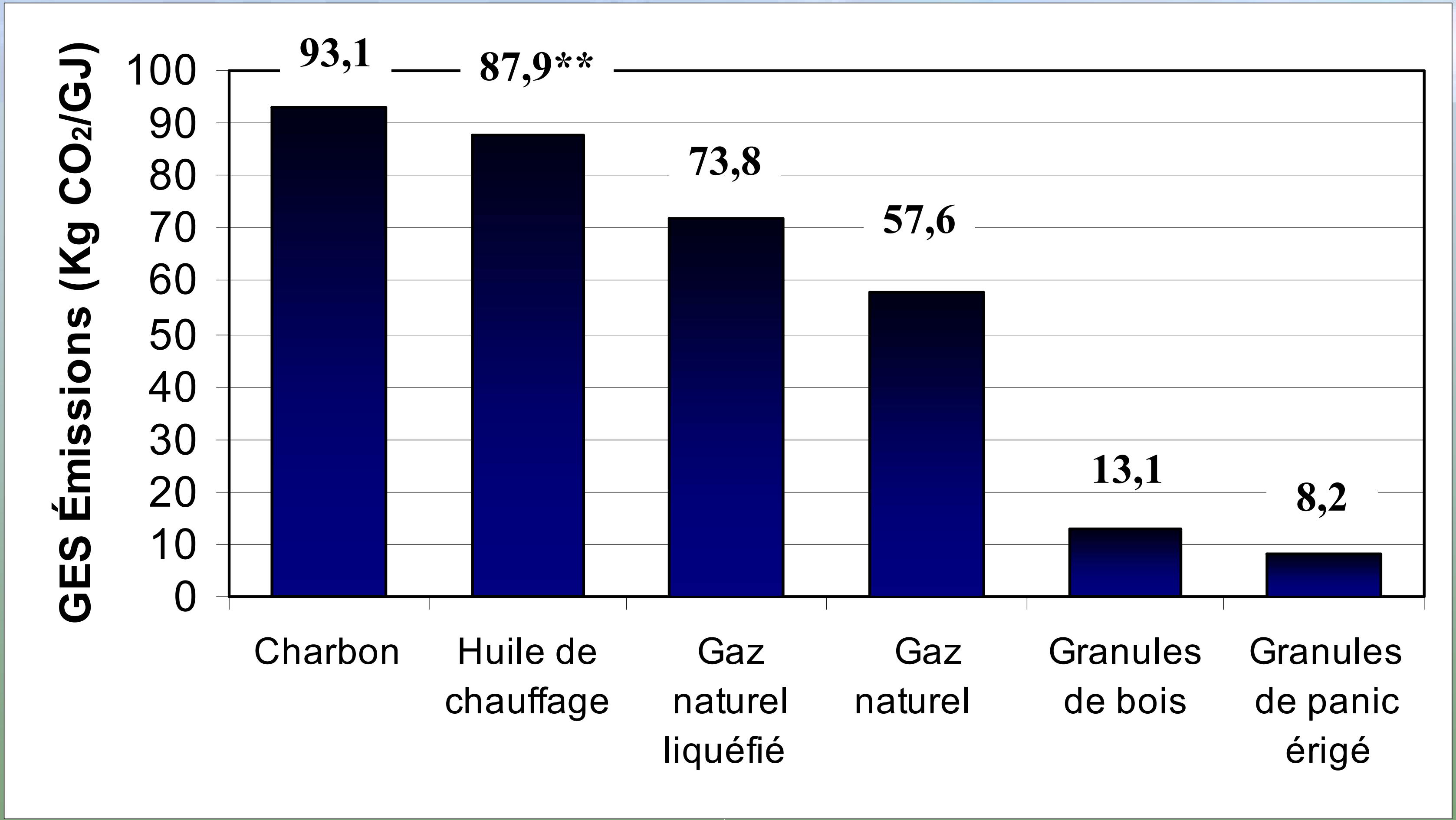
Samson et al., 2008

Harvest Period and Biomass Composition Changes

Biological Component	Fall m.c. (%)	Composition	
		Fall 2006	Spring 2007
Head	4	12.5 %	5.2%
Leaf	15	25 %	13.2%
Sheath	13	14.8 %	17.9%
Stem	25	47.7 %	63.7%

- Whole plant moisture contents was reduced to ~7% at baling in the spring

Émissions de GES des énergies fossiles *



***Basé sur GHGenius 3.9xls, Ressources Naturelle Canada, Samson *et al*, 2008**

****Basé sur un mélange d'huile typique Canadien à 48 % de provenance domestique à 52 % de provenance internationale**

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