

# Developing Energy Crops for Thermal Applications:

Optimizing Fuel quality, Energy Security & GHG Mitigation\*



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*\*Chapter 16 in Springer Science "Biofuels, Solar and wind for renewable energy" presented at International Energy Farming Congress, Papenburg, Germany March 10-12, 2009*

# 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



# 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



# Biofuels Research at REAP-Canada began in 1991

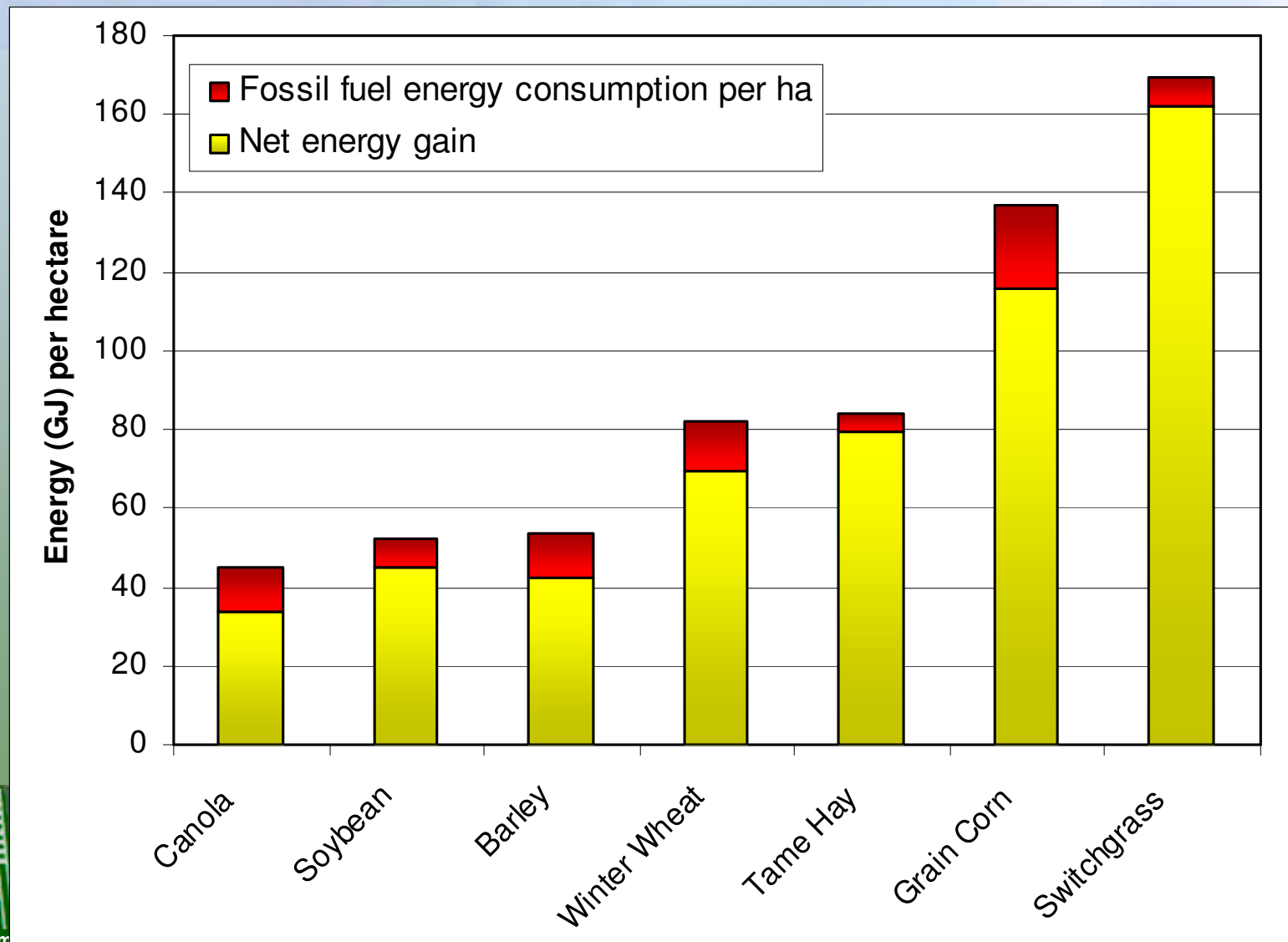


# Warm Season Grasses

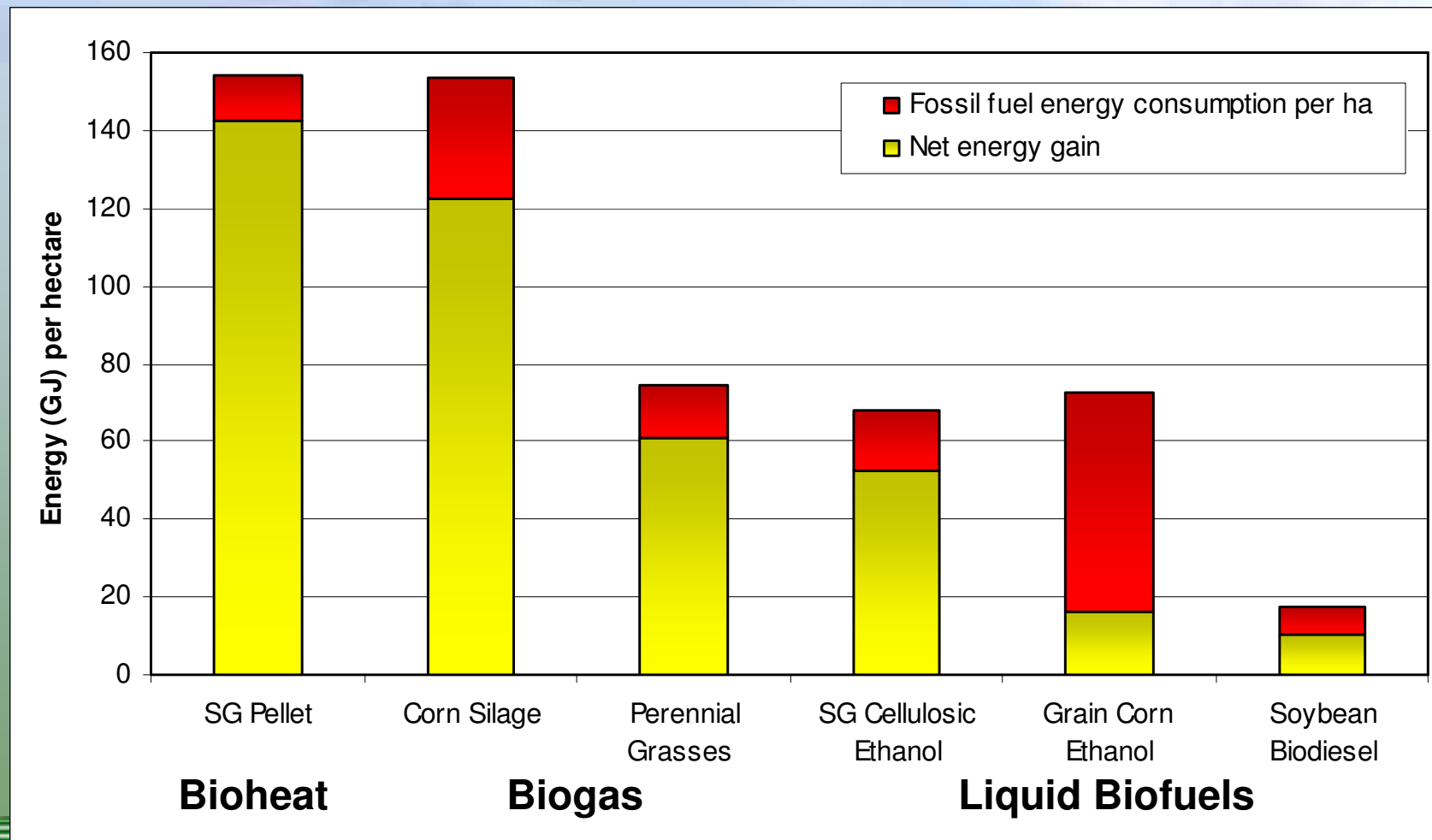
C4 Grasses such as switchgrass are ideal bioenergy crops because of their moderate to high productivity, stand longevity, high moisture and nutrient use efficiency, low cost of production and adaptability to marginal soils.



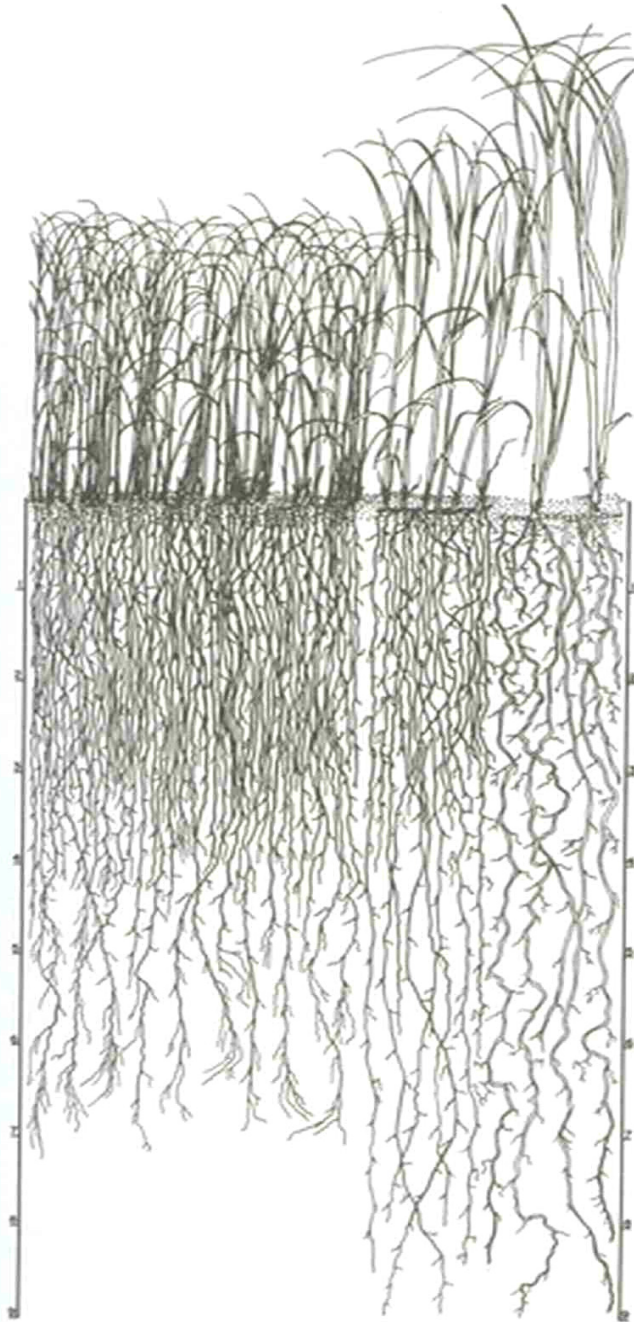
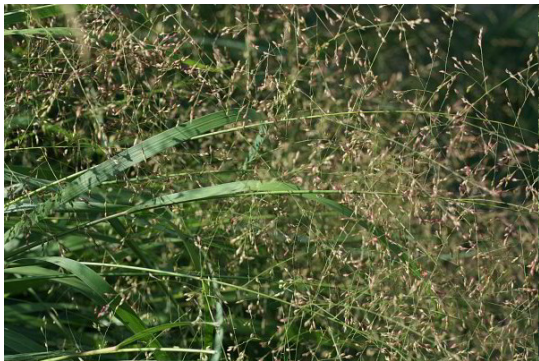
# Solar Energy Capture and Net Energy Gain of Ontario Field Crops (Samson et al., 2008)



# Harvesting Energy from Ontario Farmland for Biofuel Applications (Samson et al., 2008)



# Switchgrass



# Prairie Cordgrass







**TECUMSEH SWITCHGRASS (115-120 days)**

# 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



# Delayed Harvest Cause Important Losses

- SG Research in Quebec (Girouard and Samson 1997) and Pennsylvania (Adler *et al.*, 2006) indicated recovered spring biomass is 46% and 49% of fall biomass using a mower conditioner and baling system

## Losses come from:

- Loss of cell solubles (~7-10%)
- Field breakage (~20-25%)
- Harvest system losses (~20-25%)



# Where Are We Primarily Losing Biomass Through Overwintering?

Botanical Component	Fall yield (kg/ha)	Spring yield (kg/ha)	Net loss (kg/ha)	Net loss (%)
Head	1,363	364	999	73%
Leaf	2,725	924	1,801	66%
Leaf sheath	1,613	1,253	360	22%
Stem	5,199	4,459	740	14%
<b>Total</b>	<b>10,900</b>	<b>7,000</b>	<b>3,900</b>	<b>36%</b>

# Fall Switchgrass Harvest



**FALL**



**WINTER**



**SPRING**









# 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

# Can we make a wood pellet substitute from grass?

- Need to keep stems somewhat thin (3.5- 5 mm thick and stem wall (0.7mm thick)  
(thick stems like miscanthus problematic for aerosol pollution)
- Cultivate on sandy soils (have lower silicic acid content than clay soils which makes lower ash fuels)
- Increase stem fraction through breeding and species choice
- Separate stems from leaves through air fractionation



# 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**

# Impact of Soils on Ash Content

Studies with reed canarygrass in Sweden (Pahkala et al 1996) found ash contents of:

- Sandy soils 1.3%
- Organic soils 1.9%
- Clay soils 4.9%

In eastern Canada spring harvested whole plant switchgrass 2.75% & 3.21% ash on sandy loam and clay soils respectively (Samson et al 1999)

*Clay soils have higher monosilicic acid content than sandy soils which result in more silica uptake into plants creating higher ash fuels*

# Big Bluestem: a lower ash pellet than switchgrass?

## Big Bluestem

Native ecovars 60% stem

## Switchgrass

Native ecovars 45-50% stem



# How close are grass stems to wood residues as pellet feedstocks?

Quality parameter	Wood residues	Switchgrass Stems	Difference
Energy	20.3 GJ/t	19.55 GJ/t	-3.7%
Ash	0.6%	1.03%	+72%

**Will homeowners be content with a 1% ash pellet that doesn't clinker?**

# Plan to introduce grass pellets into small boilers and then pellet stoves market





# Heat Generation GHG Offsets

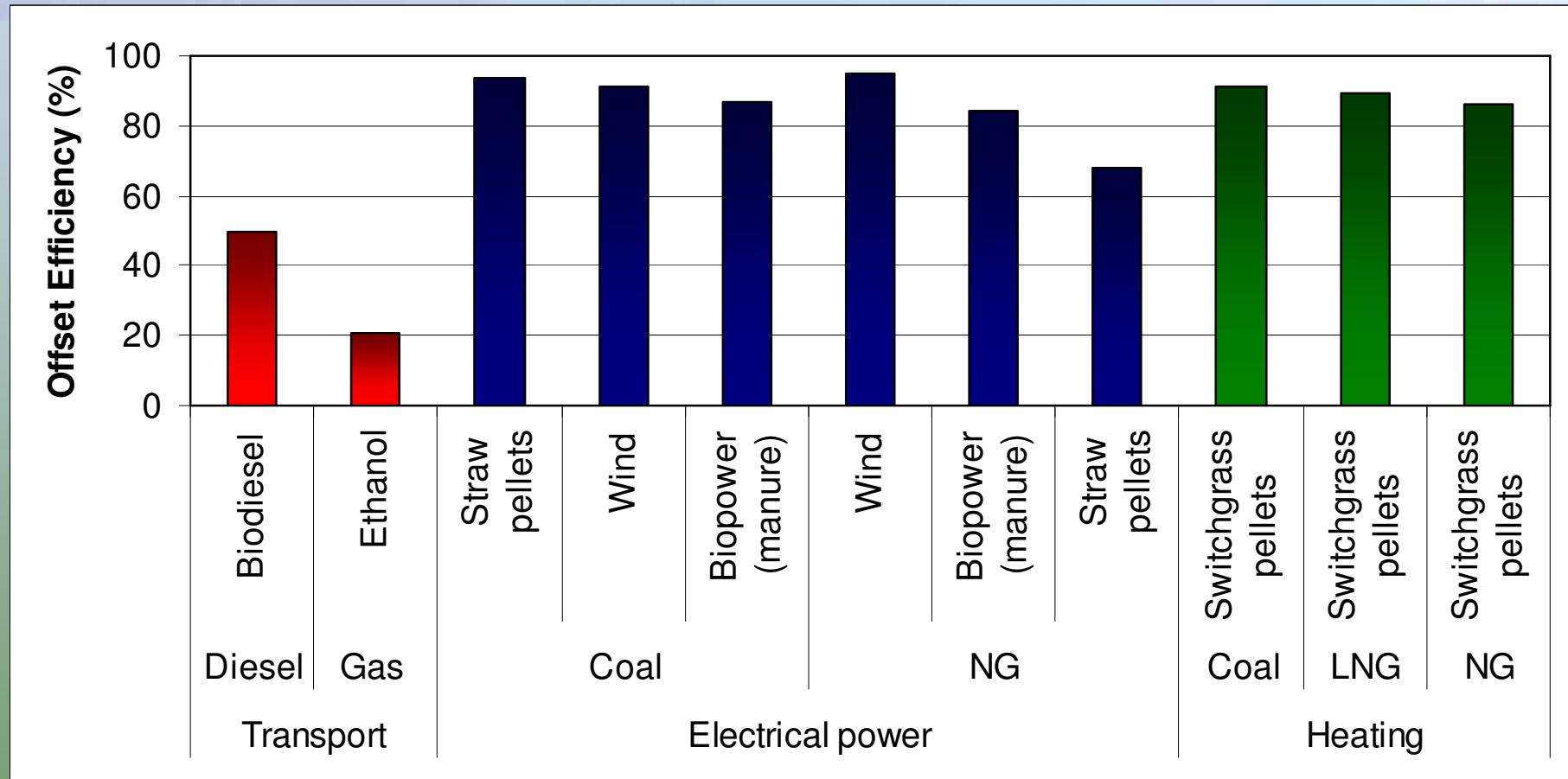
Fossil Fuel		Renewable Fuel		Net offset (%)
	kg CO <sub>2</sub> e/GJ		kg CO <sub>2</sub> e/GJ	
Coal	93.4	Switchgrass pellets	8.2	91
LNG	87.9	Switchgrass pellets	8.2	90
Natural gas	61.6	Switchgrass pellets	8.2	87



Samson and Bailey Stampler, 2009



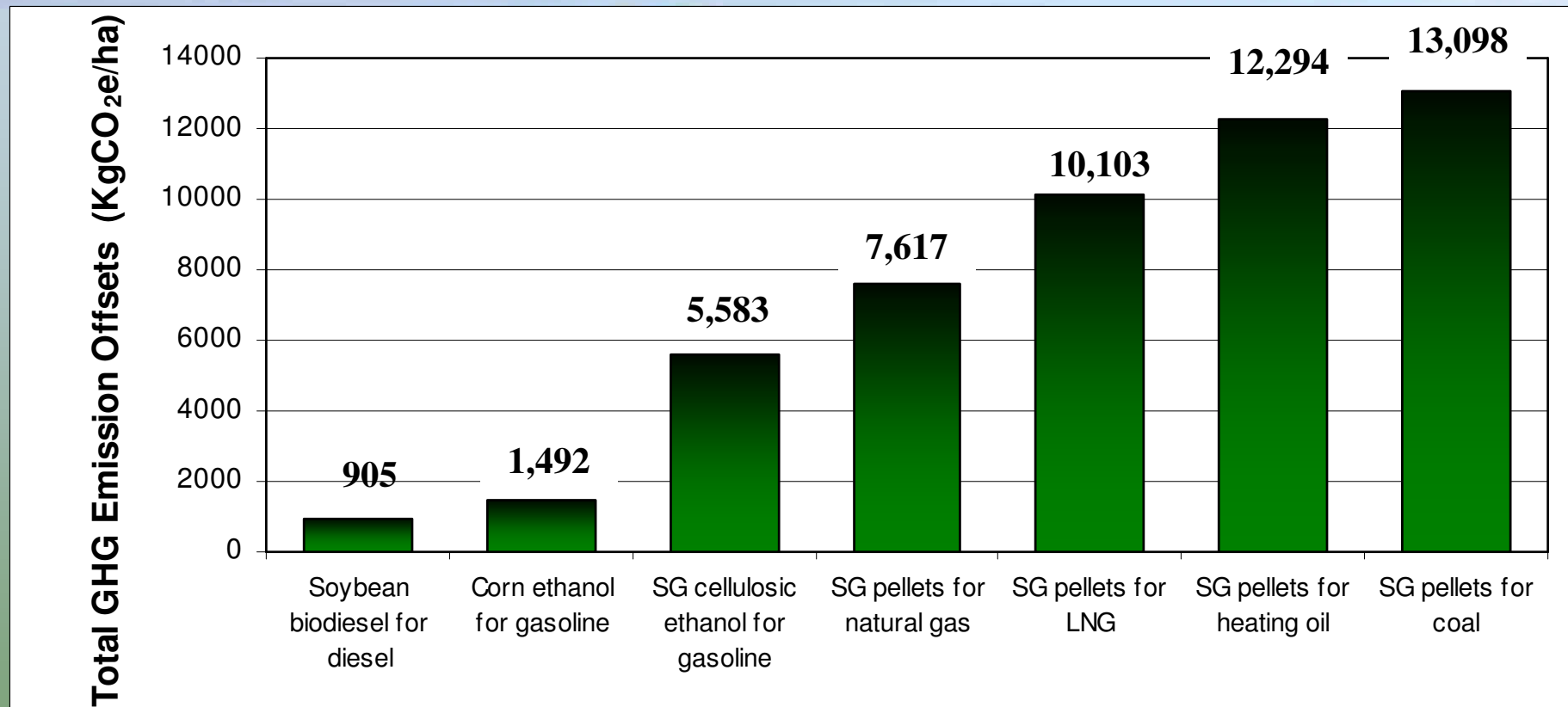
# Offset Efficiency of Biofuel Options (Samson et al 2008)



NG-natural gas; LNG-liquefied natural gas

Samson et al. 2008

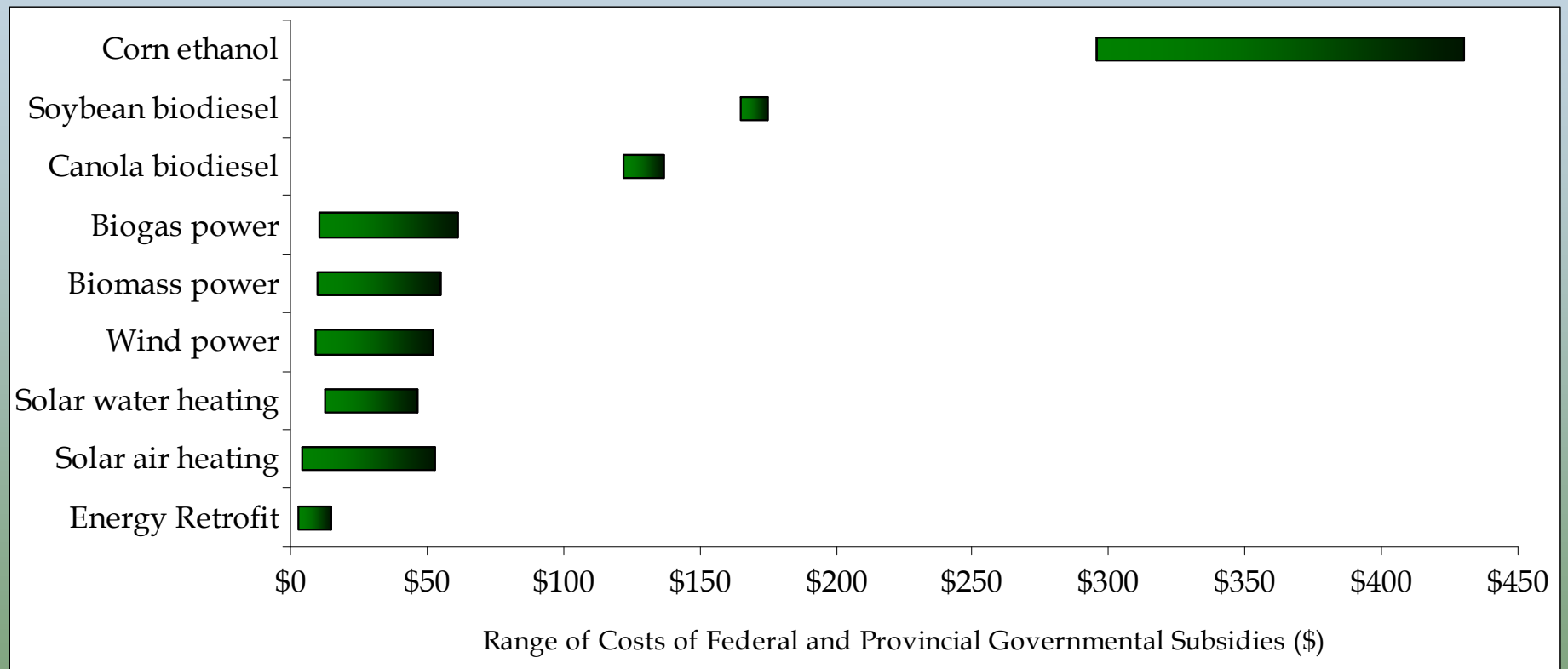
# GHG Offsets From Ontario Farmland Using Biofuels



**SG= switchgrass; LNG= liquified natural gas**



# Costs required to offset 1 tonne CO<sub>2</sub>e with Provincial & Federal Incentives in Canada



**Note: No subsidies exist for pellets, a \$2/GJ subsidy would cost about \$25-\$40/tonne CO<sub>2</sub> avoided**



**Samson and Bailey Stamler, 2009**

# Summary and Conclusions

- Warm season grasses represent the most resource efficient way to capture solar energy through crop production
- WSG biomass quality for combustion is superior to other agri-fibre fuels
- There are no technical barriers to develop the grass pellet industry in Canada (or likely eastern europe)

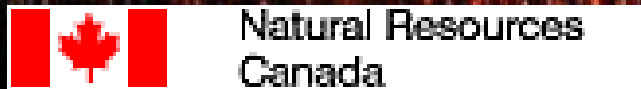


# Summary (Continued)

- Without subsidy the most likely market to emerge is in small boilers and stoves as a wood pellet replacement (or supplement)
- With political leadership to create subsidy reforms grass pellets will become a major renewable energy industry in the industrialized world

# Thank You!

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