

Opportunities for Growing, Utilizing & Marketing Bio-Fuel Pellets



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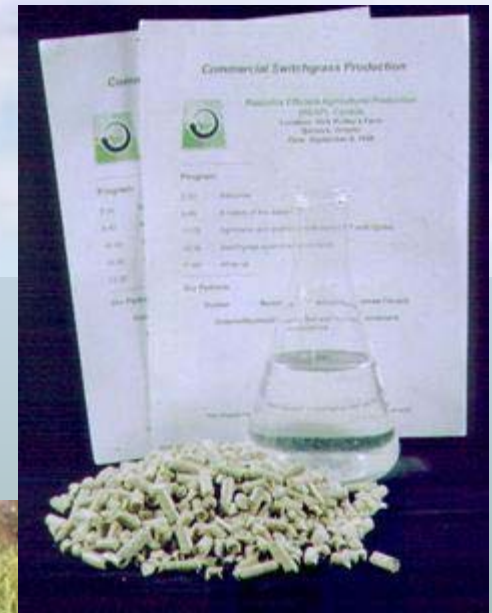
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REAP-Canada

- A leading international agency dedicated to the development of ecological energy, fibre and food production systems
- A world leader in research and development of agricultural bio-fuels and bio-energy conversion systems
- Community-based Development Projects in China, the Philippines and West Africa



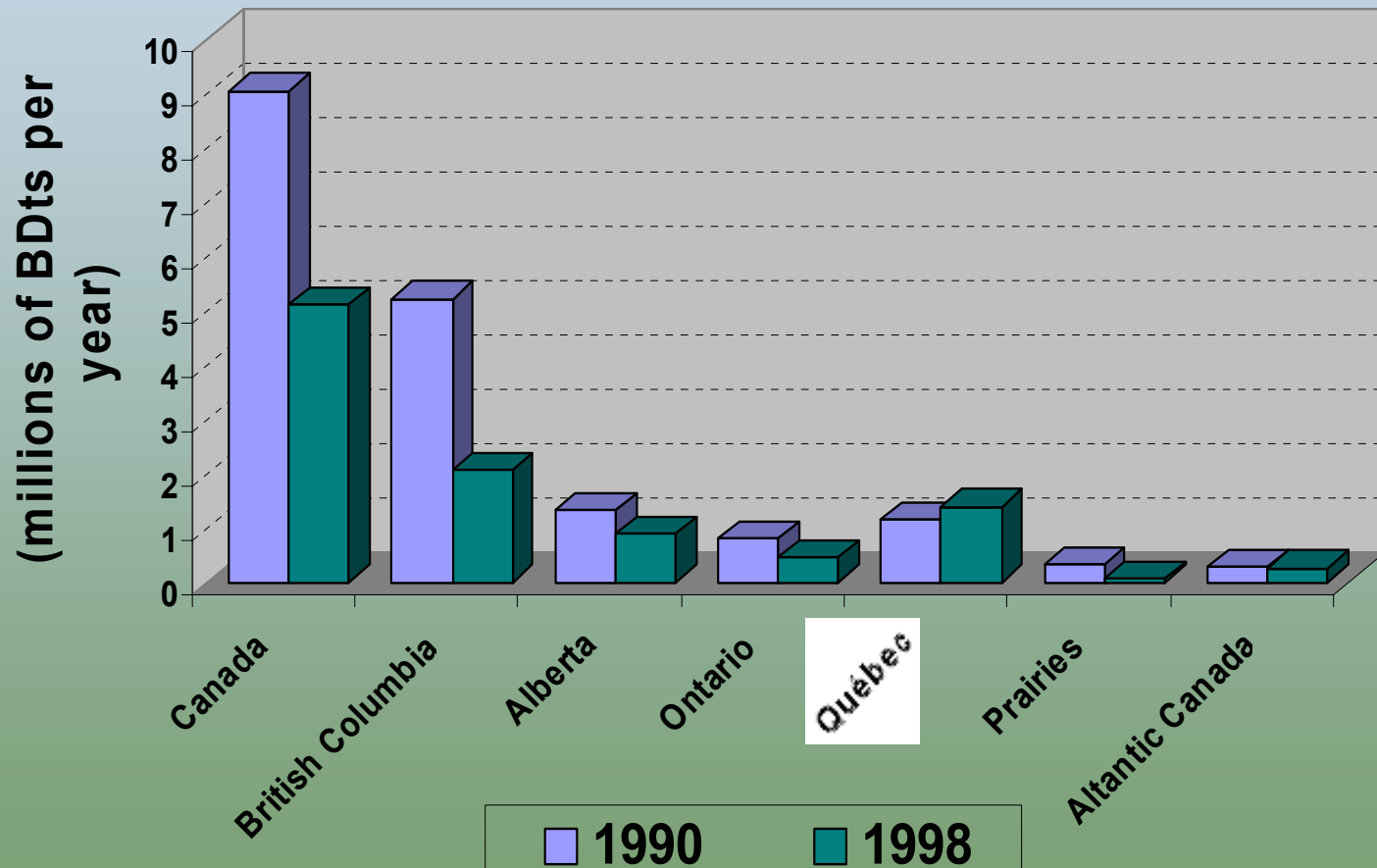
To economically provide large amounts of renewable energy from biomass we must:

- As efficiently as possible capture solar energy over a large area
- Convert this captured energy as efficiently as possible into a convenient and low cost end use application

SO WHAT ARE OUR OPTIONS?



Canada's Surplus Wood Residues (1990-1998) (Hatton 1999)



C3 vs C4 Plants as Biomass Crops

C3 Plants

- Greater chilling tolerance
- Tolerant of imperfectly drained soils
- Utilizes solar radiation effectively in spring and fall

C4 Plants

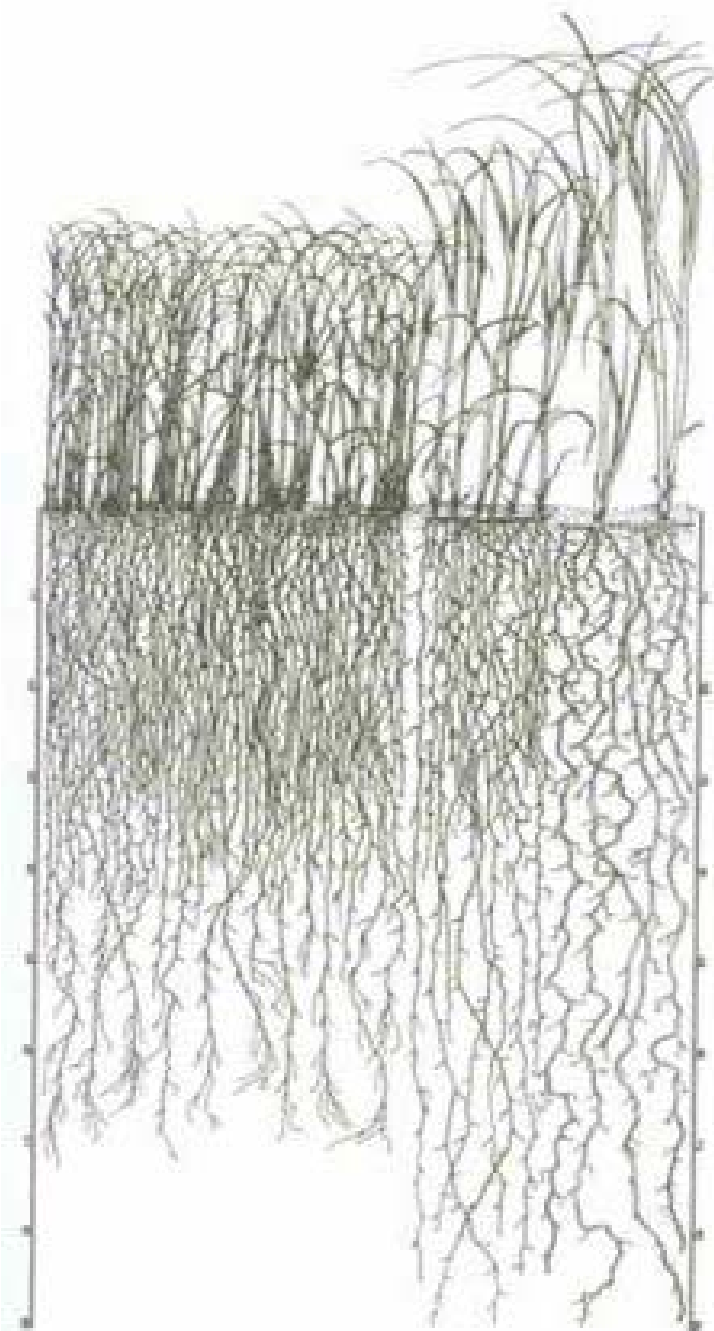
- Responsive to warming climate
- Greater water use efficiency
- Utilizes solar radiation effectively at high temperatures
- Modest levels of ash



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









Introduction to switchgrass

Fast growing warm season perennial grasses have been identified as ideal candidates for biomass fuel production due to their high net energy yield per hectare and low cost of production.

Switchgrass (*Panicum virgatum*), is an ideal biomass energy source because of its 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.

Switchgrass has an energy output to input ratio of approximately 20:1 and can typically produce 185 GJ of energy per 10 tonnes of biomass from land that is often of marginal crop producing value.

Switchgrass can be densified into a pelletized biofuel and used for space heating purposes with a close couple gasifier pellet stove. This energy pathway was evaluated with support from Natural Resources Canada.



Desirable Characteristics of Switchgrass as a Biomass Crop

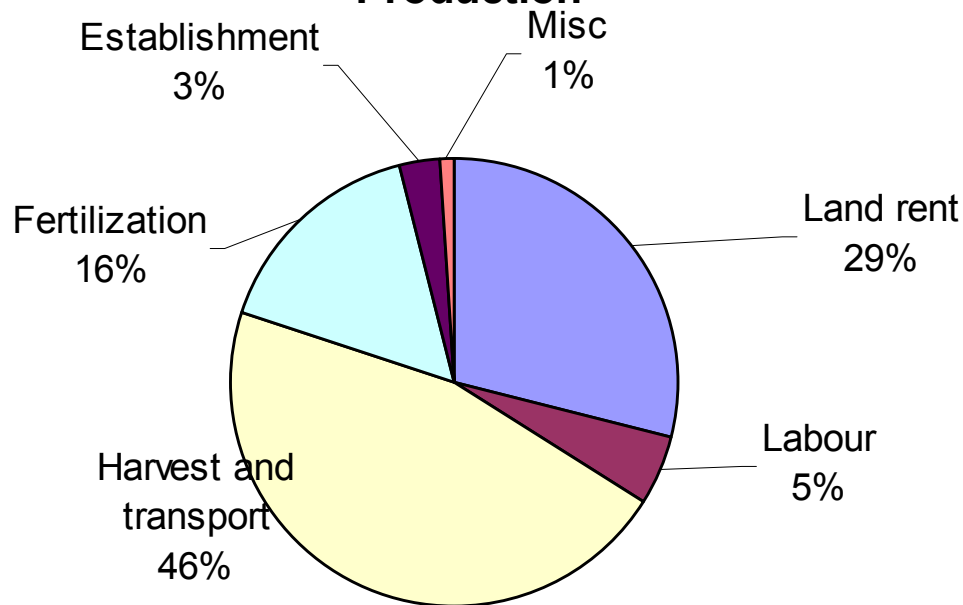
- Moderate to high productivity
- Low maintenance
- Tolerates acidic soils
- Stand longevity
- Low NPK requirements
- Moisture efficient
- Soil restoring properties

Economics of Switchgrass Production

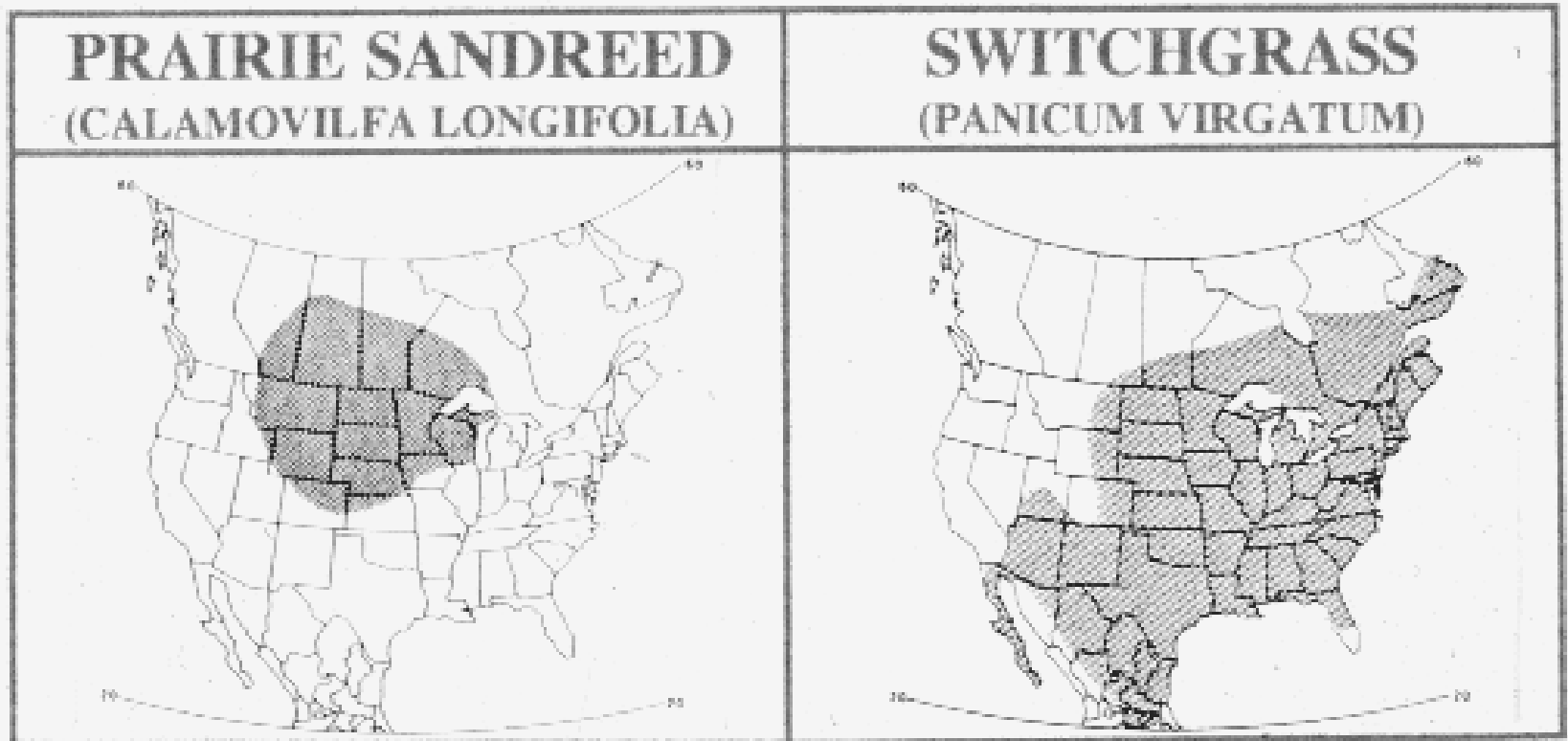
● Fall harvesting
\$41-57_{CDN}/tonne

● Spring harvesting
\$46-68_{CDN}/tonne

Economic Cost Breakdown for Fall Switchgrass Production



Native Range of Selected C4 Grasses



Farmland in North America and Potential for Biofuel Production

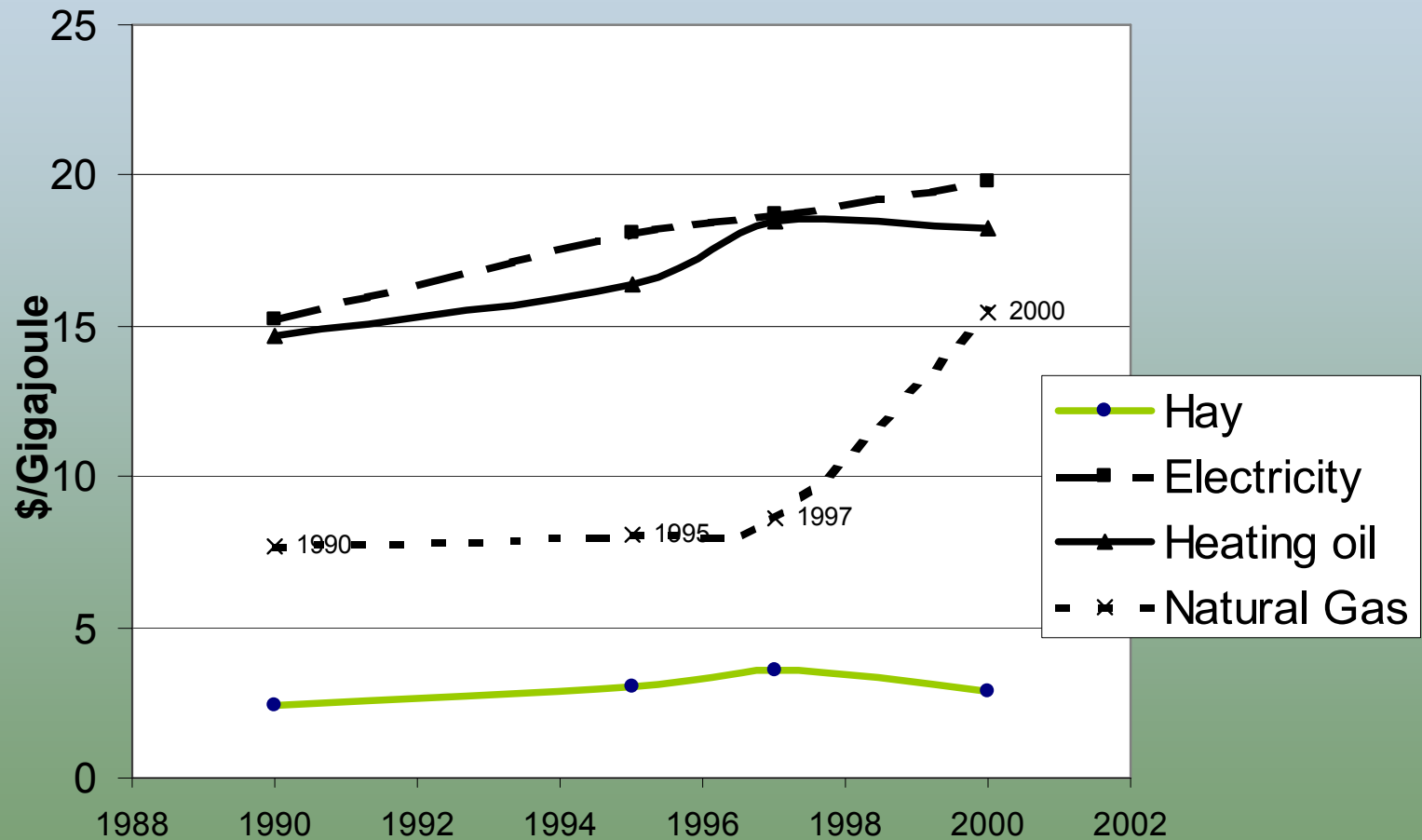
Land use	Millions of Hectares	Area for biofuel production* (million ha)	Potential perennial grass production** (million tonnes)	Solar energy collected (Billions GJ)
Canada	68	9.5	55.8	1.03
U.S.A.	377	52.4	425	7.86

** Estimated 13.9% land converted to bioenergy grasses*

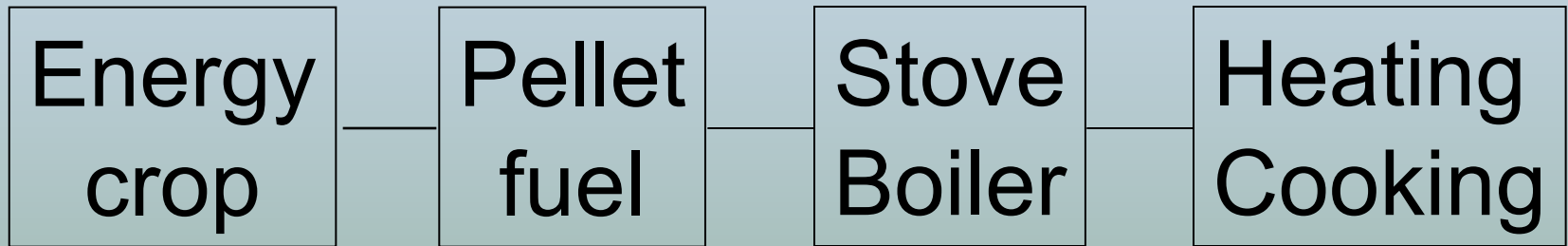
*** Assumed hay yields of 5.9 tonne/ha in Canada, 8.1 tonne/ha U.S*



Comparative Costs of Hay Prices vs. Residential Heating Costs in Manitoba



Modernizing the Bioenergy Heat Production Chain



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 $\frac{1}{4}$ or $\frac{5}{16}$ 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.

Overwintering switchgrass reduces the potassium and chlorine content which improves overall biomass quality. Switchgrass biomass quality is also better when grown on sandy soils.

Spring harvested switchgrass has an ash content of approximately 3-3.5%. It has an energy content of 19.2 GJ/tonne, only 3% lower than wood and 7% greater than wheat straw.

The densification of switchgrass into fuel pellets eases the combustion and handling problems normally associated with the bulky nature of biomass.



Production and economics of switchgrass pellets

In terms of pelleting, switchgrass behaves similarly to alfalfa, and it is significantly easier to pellet than hardwood or softwood fibre sources.

The use of switchgrass as a pelleting material can reduce pellet production costs by increasing the throughput of a 150HP pellet machine to 6.9-10.9 tonnes/hr compared to 3.1 for hardwood and 4.5 for softwood.

Switchgrass is an economically attractive feedstock as it requires minimal drying compared to wood.

Switchgrass pellets can be produced in closer proximity to more densely populated areas than can wood fuel pellets, thus reducing transportation costs and making bulk handling more feasible.









Summary of preliminary feedstock production costs (\$CDN/tonne)^a

	Wood pellet costs	Projected switchgrass pellet costs
Feedstock	\$ 34.35	\$46-\$68
Drying	\$11.93	\$0
Direct Pelleting Costs	\$59.00	\$25.29-39.33
Bagging	\$19.25	\$19.25
Total cost	\$124.53	\$90.54-\$126.58

^aDirect pelleting costs are based on:

30 lbs./hr/HP (177.6 kg/hr/MJ) for wood residues

45-70 lbs/hr/HP (266 – 414 kg/hr.MJ) for switchgrass



The Dell-Pointe Pellet Stove

**This close coupled gasifier
pellet stove was designed
to efficiently burn
moderately high ash fuels
and feed grains**



Combustion performance of switchgrass fuel pellets

Dell-Point Technologies (Blainville, QC), in partnership with the Natural Resources Canada Advanced Combustion Laboratory, has developed a close couple gasification pellet stove with an overall efficiency of 81-87%.

The stove design is such that a lower operating temperature exists in the bottom of the gasifier where the first stage of the combustion occurs. The ash is slowly augered out allows the ash to remain in the auger fall through the grate into the ash pan, thus reducing clinker production.

Burning switchgrass provided an efficiency of 82%-84% when tested by the CANMET combustion laboratory.

Grains (including rye, barley, oats, wheat and corn) are now also being burnt Dell-Pointe Stove.

Particulate levels from switchgrass combustion were greater than those obtained for wood, with peak levels of 2.5 g/hour at the high range setting. However, the values were well below the 7 g/hour EPA limit for pellet stoves.



Reducing heating costs and CO₂ emissions with switchgrass biofuel pellets

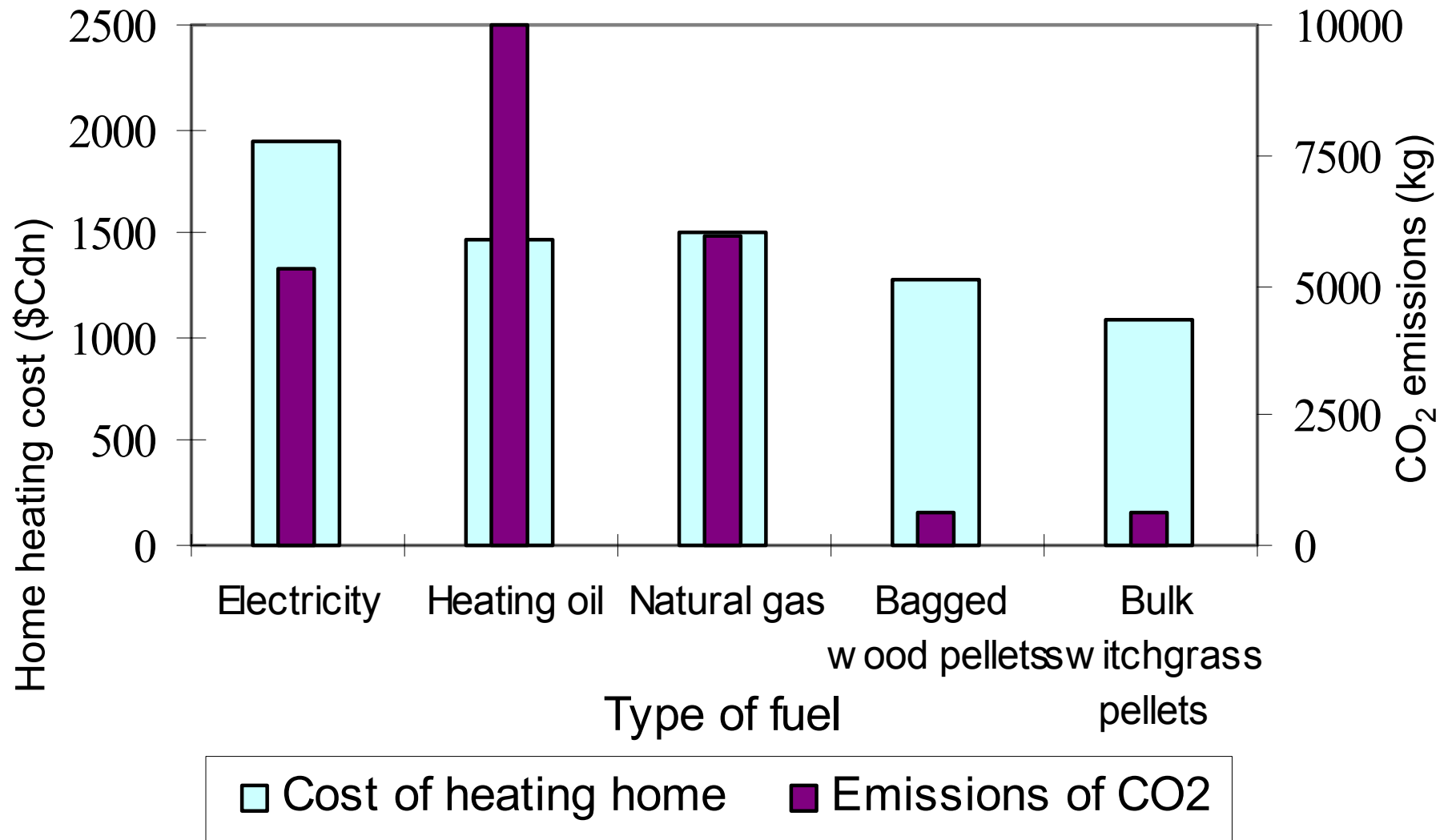
In North America, biomass energy from grass pellets and crop residues could play an important role in reducing the economic and environmental costs associated with fossil fuel use.

The rising price of heating oil and natural gas will increasingly make the replacement of these fuels with biomass energy more financially attractive to consumers.

The bottom line is that relative to heating oil systems, switchgrass pellets have the potential to reduce fuel heating costs and greenhouse gas emissions by approximately 30% and 90% respectively.



Fuel costs and CO₂ emissions associated with home heating in S.W. Quebec



Assumptions:

Electricity has an energy content of 3.6 MJ/kWh, a delivered fuel value of 6.87 cents/kWh, a CO₂ loading value of 52.2 kg CO₂/GJ and is converted at 98% efficiency, Approximate Canadian electrical mix: 63% hydro-power, 15% nuclear, 16.5% coal, 3% oil, 2% natural gas

Heating Oil has an energy content of 0.0382 GJ/l, a delivered fuel value of 46.01 cents/l, a CO₂ loading value of 81.8 kg CO₂/GJ, and is converted at 82% efficiency

Natural Gas has an energy content of 0.0375 GJ/m³, a delivered fuel value of 47.85 cents/m³, a CO₂ loading value of 50.6 kg CO₂/GJ, and is converted at an average efficiency of 85%

Bagged Wood Pellets have an energy content of 19.8 GJ/tonne, a delivered fuel value of \$207/tonne, a CO₂ loading value of 5.3 kg CO₂/GJ, and are converted at 82% efficiency

Bulk Switchgrass Pellets have an energy content of 19.2 GJ/tonne, a delivered fuel value of \$172/tonne, a CO₂ loading value of 5.3 kg CO₂/GJ, and are converted at 82% efficiency.

All delivered fuel values include taxes of 7% GST and 7.5% TVQ.

*Heat estimates made for a new detached 2000 sq. foot home with a heat requirement of 100 GJ.
The analysis does not include capital costs associated with equipment.*



Switchgrass production and pelleting: Energy analysis

Pellet conversion facilities are much smaller (200 tonne/day) than other large biomass processing industries (1500 tonne/day), and thus can be located in closer proximity to the site of switchgrass production.

If 5% of the landscape is converted to switchgrass and a harvestable yield of 10 tonne/ha is obtained, switchgrass can be sourced within a 20 km radius of a pelleting plant, versus a 60 km radius for a large industrial user.

This shorter radius would reduce the energy used in delivery by approximately 2/3. Due to the difference in hauling differences, the total energy cost of switchgrass production for a large industrial user is estimated to be 0.91 GJ/tonne, while that of a pellet plant is 0.79 GJ/tonne.



Energy inputs and outputs associated with of switchgrass as a pelleted biofuel

Process	GJ/tonne
Switchgrass establishment	0.028
Switchgrass fertilization and application	0.460
Switchgrass harvesting	0.231
Switchgrass transportation	0.072
Pellet mill construction	0.043
Pellet mill operation	0.244
Management, sales, billing and delivery of pellets	0.193
Total Input Energy	1.271
Total Output Energy	18.5
Energy Output/Input Ratio	14.6



Net Energy Gain and Land Use Efficiency

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



Conclusions

Converting switchgrass into heat, using close coupled gasifier stoves and furnaces, is proposed as the biofuel system with the greatest potential to produce useful net energy from agricultural land and to displace oil imports with the least government intervention.

This energy transformation pathway appears to accurately fit the definition of a ‘soft energy path’, due to its following characteristics:

- It is powered by a renewable source of energy**
- It provides power sources which are multiple, small-scale and local, rather than few, large-scale and distant**
- It is a flexible and comparatively low technology system, facilitating its understanding and utilization**
- Is matched in terms of both scale and energy quality to its end-use application.**

