Switchgrass

A living solar battery for the prairies

A grandiose scheme is proposed to replant 35 million acres of tallgrass prairie to be used for ethanol. It would: replace all of Canada's gasoline requirements; reduce government subsidies to both the agriculture and energy sectors; not only save farms but create rural employment opportunities; prevent Canada from becoming a net oil importing nation; rehabilitate prairie soils and wildlife populations; and reduce Canadian CO2 emissions by 15%. It sounds all too good to be true; can it be?

by
Roger Samson

Since Ford introduced the mass produced automobile, people have tinkered with making ethanol out of everything, from corn to milkweed. The principal problem has been that too much energy is used to grow, harvest and process the raw material.

When all is said and done, the ethanol industry uses about as much energy as it provides. Not only is it energy inefficient, but if energy prices escalate, so does the cost of the ethanol because its' production costs are associated with fossil fuel prices. Crops which have been bred for use as food for humans or animals may not necessarily be the most efficient when it comes to using them as energy crops because the fossil fuel dependency is never broken.

In 1985, the U.S Department of Energy (DOE) began a five year program to develop a herbaceous energy crop. They screened the potential of traditional and non-traditional, annual and perennial, crop plants for their capacity in producing moderate to high biomass yields at low cost. The goal of the DOE Herbaceous Energy Crop Program was to produce competitively priced liquid fuels from biomass, with an emphasis on utilizing marginal lands that were limited agriculturally by erosion, wetness or other soil factors.

In 1991, switchgrass, a warm season perennial grass, was chosen as the model herbaceous crop species. This was done not with the assumption that switchgrass will be the only crop for biofuel development, rather that it is a very promising species which provides an opportunity to focus available resources for development of the industry.

Native species

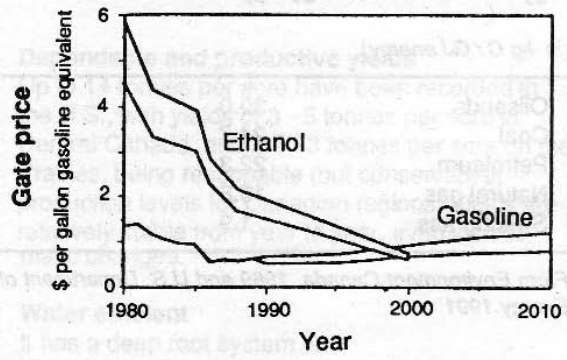
Switchgrass is not widely known in Canada despite the fact that it is a native species found in Ontario, Quebec and on the prairies in Manitoba and Saskatchewan. It's main use presently is centred in the U.S. Midwest and plain states, where it is used for midsummer forage production.It is not generally grown for hay due to its poor forage quality. Switchgrass was of considerable economic importance during the period of settlement in Manitoba, but the extensive stands of naturally-present switchgrass were reduced by overgrazing and the plowing-up of the native sod.

While switchgrass may not be the queen of forage plants, it may become the king of bio-mass crops. Several research reports from the U.S. have calculated switchgrass production costs to be less than $30.00 mt. With a breeding program aimed at maximizing biomass yields, rather than forage quality, these low production costs should be realized on a commercial basis. With a projected market value of $35.00-40.00 mt for cellulosic conversion, there appears to be significant potential for a viable industry. Compare this with the Canadian wheat industry, with a market price of approximately $2.00 per bushel and costs of production at $4.50-5.00 per bushel. In addition, there is $1.00 per bushel in government subsidies for freight assistance to move wheat out of the Prairies.

Environmental trouble

The Western grain industry is neither economically nor ecologically viable in its present form. Soil degradation on the Prairies was recently cited in *Scientific American* as one of the world's worst examples of soil degradation. One option that the federal government is looking at to deal with the problem is to set land aside. The National Soil Conservation Program would be used as a means to retire the most marginal farm land from production. A similar program called the Conservation Reserve Program already exists in the U.S. A recent economic analysis has indicated that it is a less expensive option to put land into switchgrass

Figure 1 - Gate price of ethanol and gasoline



Source: Lynd et al. Science, March 15, 1991

biomass energy production than into the Conservation Reserve Program, while at the same time achieving similar erosion control goals.

While biomass feedstock production technologies have been improving, even more dramatic has been the improvement in ethanol conversion technologies for cellulosic biomass. This was the subject of a major article in the journal, *Science*. It shows that a cost competitive process with gasoline is forecast to occur by the end of the decade and that the cost has been dropping rapidly with new advancements in biomass conversion.

One of the best kept secrets in Canada is that the nation is losing its oil self-sufficiency. Oil imports will reach $5.5 billion by mid-decade. New Canadian oil projects are also proving very expensive for the amount of oil they extract, much of which is heavy oil requiring considerable processing before marketing. It costs nearly $10 per barrel to upgrade heavy oil to higher value synthetic crude oil suitable for automobile use. The result is that although biomass ethanol may not be competitive with world oil prices at the moment, it most likely is a less expensive option than new Canadian frontier oil projects such as Hibernia, or heavy oil projects like the Tarsands.

Tapping the prairie

Potentially 35 million acres of land currently in summerfallow and surplus grain production could be made

Continued on next page

Table 1 - Ethanol yield of Switchgrass

Switchgrass Yield:	2.8 t/ac	7.0 t/ha
Ethanol Yield @ 400 litres/ tonne:	1120 l/ ac	2800 l/ha
Land base:	35 million ac	14 million ha
Ethanol Output:	39.2 billion l	39.2 billion l

Switchgrass biomass yield as estimated from yields obtained in the Northern U.S. Great Plains near the Canadian border.

Summary of Switchgrass as a low CO_2 loading ethanol feedstock

1. Possesses a high energy output/ input ratio
2. Ties up CO_2 by increasing soil organic matter (which contains 58% C)
3. Increases carbon stored in vegetation both above and below ground relative to present land use (summerfallow and annual grains)
4. Energy for conversion is provided by burning of lignin leftover after the ethanol extraction (rather than using fossil fuels)

Continued from previous page

available for the development of an ethanol industry based on tallgrass species such as switchgrass. This would be made up of the 20 million acres currently in summerfallow in Western Canada, and 15 million acres currently in spring cereals. It would represent a 30% reduction in cereal acreage in Canada The most marginal cereal growing areas would be targeted first.

Current Canadian gasoline consumption is approximately 30 billion litres per year, which would require approximately 37.5 billion litres of ethanol for substitution (One litre of gas can be replaced by 1.25 litres of ethanol).

A tallgrass-based ethanol industry of this size could entirely replace Canada's gasoline requirements, as well as help Canada take a considerable step towards reaching CO_2 reduction goals. Switchgrass not only requires lower energy inputs for growing, but also requires few energy inputs for ethanol conversion. The steam and electricity used to convert the switchgrass to ethanol can be derived from the combustion of the lignin (approximately 7% by composition) leftover after the ethanol extraction process. This represents a major difference compared to the grain ethanol industry, which requires large energy inputs from fossil or nuclear energy sources for its conversion.

Effects on Canadian CO_2 Emissions

As a renewable biomass source of energy, switchgrass has tremendous potential to reduce CO_2 emissions relative to other energy sources (Table 2). CO_2 emissions from the production and combustion of gasoline are approximately 2.5 kg CO_2 per litre or 75 million tonnes of CO_2 from the 30 billion litres of gasoline consumed in Canada annually. Assuming ethanol derived from switchgrass yields 10% the carbon of gasoline (due to the carbon associated with energy inputs in growing and transporting the switchgrass), it would release 7.5 million tonnes of CO_2. The resulting net annual reduction to Canadian

Table 3 - Relative CO_2 Emissions Per Unit of Energy For Various Energy Types.

(in kg C / GJ energy)

Oilsands	30.0
Coal	24.7
Petroleum	22.3
Natural gas	13.8
Switchgrass	1.9

From Environment Canada, 1989 and U.S. Department of Energy 1991

CO_2 emissions (67.5 million tonnes) from a switchgrass based ethanol industry would be approximately 15% (with current Canadian CO_2 emissions of approximately 450 million tonnes). As well, the change in land use from summerfallow and wheat, to perennial tallgrasses, would store an additional 810 million tonnes of CO_2. This would come from increased carbon storage in above and below ground vegetation (270 million tonnes), and restoration of soil organic matter levels (540 million tonnes).

Large Industry

An ethanol industry based on biomass, producing 40 billion litres annually, could be established by building four hundred ethanol plants, each one with a capacity of 100 million litres. This would provide thousands of jobs to some of the most disadvantaged areas in Canada. It would greatly stimulate the farm economy as it would bring into production 20 million acres of summerfallow that are currently bringing in no income. As well, it would improve net returns to farmers by increasing crop yields while lowering inputs; the remaining cereal and oilseed acreage would be rotated with

Continued on page 8

Steps in Conversion of Grass to Ethanol

1. **Pre-treatment**
   Steam explode material to rupture cells making carbohydrates available to attack by enzymes.
2. **Enzymatic Hydrolysis**
   Enzymes are added to convert the carbohydrates into fermentable sugars
3. **Fermentation**
   Sugars are fermented through the addition of yeasts and bacteria to make ethanol
4. **Distillation**
   Dilute ethanol is purified out of the broth
5. **By-product Utilization**
   The lignin that is leftover after the extraction of ethanol is burnt to provide the steam and electric ity to drive the conversion process