Nuffield
Farming Scholarship
Report

Alternative Energy Crops:
Grown in Rotation with Potatoes

Eric Ritchie

November 2008

Contents

Executive Summary

My Nuffield study has evolved into exploring the alternative energy crops that can be grown in a complementary rotation with potatoes. In New Brunswick, our crop cycle consists of a year of potatoes followed by either a wheat or barley crop under-seeded to a forage / grass. Cereal crops have suffered two issues in the past three plus years that have reduced profitability, these being poor commodity prices and reduced yield and quality due to Fusarium contamination. A large percentage of the crop having to be dumped for high DON levels. Farmers are loosing money on their rotation crops.

New crops have included switch grass, coppiced willow and oilseed crops for biodiesel, and uses for existing crop residue. Incorporating a biofuel crop as a replacement to traditional fuels must overcome a number of issues:

- Fuel combustion systems need to incorporate easy of use and flexibility in biofuel sources.
- Biofuel sources need secure long term contracts that provide operators with a measure of comfort to invest in new technology.
- Biofuel combustion and handling systems require additional operator attention and can incur additional costs.
- Emission control limitations have been implemented in Europe and there is a shift in Canada to follow.
- Farmers may be viewed as taking a lead role in reducing climate change by sequestering carbon in long term perennial cropping systems.

Of the new crops reviewed the use of cereals in the form of direct burning for energy provides an encouraging option. Oats are part of a potato rotation, and do not involve further transformation into a fuel source, thus having a high energy balance. Benefits include:

- Farmers are experienced with crop production for cereals and have a high degree of expertise.
- Infrastructure in place to grow these crops, no new equipment needs to be purchased.
- Ever increasing energy prices are improving the feasibility of crops as energy sources.
- Technology to utilize these crops for energy has taken great leaps forward in efficiency.

When considering traditional food crops for non traditional uses as a fuel crop, I unexpectedly experienced resistance in Europe. There is a mindset that a food crop remains a food crop.

A field trial at the McCain Research Farm was conducted to evaluate oats under a low input management scheme to reduce the cost per tonne with the desire to provide a comparable fuel source competitive with fossil fuels. Reduced tillage, fertility rates and weed control in rotation with potatoes did not negatively affect oat yield.

Acknowledgments

I would like to thank:

My Sponsors:

- Nuffield Canada, John Lohr my mentor
- New Brunswick Department Agriculture and Rural Development, Hon. Dale Graham & Hon. David Alward
- McCain Foods (Canada), Dr. Yves Leclerc, Allison McCain
- McCain Foods USA, Inc., Leigh Morrow, Laurie Jecha-Beard
- Potatoes New Brunswick, Ron Piper
- Jolly Farmer Products Inc., Jonathan English
- Syngenta, Dave Thompson
- New Brunswick Institute of Agrologists, Greg Sweetland

The experience could not have happened without the generous support of willing organizations who believed in me.

Participants in the three year research trial "Reduced Cereal Inputs"

- McCain Research Farm, Gilles Moreau and staff
- McCain Fertilizer, Darrell Simonds
- Graham Farms, Steven Graham
- Kilpatrick Farms, Brian and Jared Kilpatrick
- Hillview Farms, James Banks
- Taylor's Feed and Tire, Robert Taylor
- Floyd Ritchie

The application of research to address real life issues can teach us so much. To question, hypothesize, decipher, conclude and readjust our thoughts.

To past scholars who freely gave of their time to accompany me on site visits.

- Jack Rigby, Ontario
- Mathew Swain, England
- Michael Kyle, Northern Ireland
- Simon Beckett, England
- Tim Pratt, England
- Campbell Tweed, Northern Ireland
- Philippe Quignon, France

To hosts along the way, who graciously opened their homes and hospitality

- Jack and Christine Greydanus, Ontario
- Rosemary and Terry Brennan, Northern Ireland
- Catherine Lamont and Franck Deneux, France

And to my family

- Lorelei, Cole, Drew, and Kate

There is no greater gift than family, and I have had the benefit of a loving, giving family.

Forward

Western New Brunswick has predominantly a shallow clay loam soil with a gravelly sub-soil and bedrock outcroppings throughout. Fields are undulating and the topography presents sharp knolls and valleys with water courses, swales and swampy land. This translates into productive farm ground albeit prone to soil erosion. Traditional family farms raised cattle, hay and grain for feed and potatoes for sale. Historically the area had concentrated on the sale of tablestock potatoes into the Ontario, Quebec, and Eastern United States markets. With the advent of the Quick Service Restaurant (QSR) in the 1960's the processing of potatoes into French fries and potato products, much of the industry shifted its focus to supply for the growing demand of that market. Geographically the area is ideally located near a days shipping distance to the largest US population centers of New York, Philadelphia, Washington and Boston.

At the same time much of the rural population was leaving the farm for careers that did not involve agriculture. This out migration continued with individuals leaving their rural communities for urban centers, (similar scenario across all rural Canadian farm communities). This has required a high degree of mechanization to reduce the demand for a seasonal work force. Confounding this issue was the decline in the livestock industries in the Atlantic Provinces of Nova Scotia, Prince Edward Island and New Brunswick. As the critical mass of beef, pork and poultry have declined, so has the processing of these commodities. Consolidation and relocation of slaughter facilities resulted and continued the demise of the animal portion on many farms. This is not to say that there is no longer livestock in the three provinces, it does mean that the numbers continue to decline. With this decrease in animal numbers has come a drop in demand and subsequent value for livestock feed.

Cereals, traditionally oats, but lately barley and to a lesser extent wheat, have been the crops rotated with potatoes. Typical rotations during the 1980's would have involved a potato crop followed by barley and then potatoes. Today that rotation has been extended to include a forage crop as well, either harvest in the form of hay or plowed under as a green manure crop. These crops are often red clover or rye grass. Ideally potatoes are only planted one year out of three or a minimum of two years out of five. Lengthening the rotation between potato crops has seen a significant improvement in tuber yield and quality.

Through the period of the 1990's potato production in the North American market was expanding and demand for potatoes was a crop that provided a positive financial return on investment. Although grain prices were at historical lows, the revenue from the potato crop could carry the losses from the other rotation crops. That comfort level disappeared in the new century as potato crop supply outpaced demand and prices decreased.

World wide issues have also entered the equation. As the emerging markets of the "BRIC" nations (Brazil, Russia, India and China) grow, the demand for fossil fuel based oil has seen unprecedented swings in price. This increase in the price of oil has seen the resurgence in interest for alternative fuels, both from a cost stand point but also a security of supply stand point. The question continues to be asked “Will we have enough energy”.

As our understanding of the environmental impact from the burning of fossil fuels has increased we are seeing the effects in the form of climate change. The reduction in greenhouse gas emissions is now regarded by governments around the world as a necessary if not urgent requirement. Additionally governments have leapt at the opportunity to support rural agriculture development in renewable energy projects as a means to revitalize declining communities.

Summarized the farm community was in need of:

- Rotation crop for the benefit and enhancement of the potato crop
- Generated additional farm gate revenue
- Provide an energy source with the benefits of greenhouse gas reduction, security of supply, and reduce the volatility in cost of purchased energy.

At the time I began the study, a group of local potato producers formed a group to address the lack of a suitable rotation crop. They too wanted to incorporate a renewable energy and provide an additional revenue source. They founded the first farmer owned company in Canada, Eastern Greenway Oil (EGO) that grows, processes and markets canola based Biodiesel and fuel additives. Being aware of this, and not wanting to duplicate work, I have concentrated my study on solid biofuel options.

My objectives thus were to:

- Investigate energy crops that are complementary to a potato rotation
- Add to whole farm income
- Utilize existing farm infrastructure if possible
- On farm developed

Beginning with the end in mind, I visited a number of greenhouse operations in Canada. These farm units have a high demand for heating and an increasing demand for electricity for supplemental lighting. Faced with increasing energy costs without subsequent increases in returns, they have implemented a number of innovative alternatives to fossil fuel supplies.

Caveats

As I traveled and interviewed individuals two differing opinions arose regarding the use of food crops for energy. In Europe the opinion was unequivocal against this option. I first encounter this when meeting with the Agricultural Envoy, Yannick Dheilly at the Canadian Embassy in Paris. As we discussed the energy crops grown in France and their impact I wanted to discuss the burning of cereals. To this he quickly answered “we do not burn food”.

I later encountered the same explanation when I was meeting with an Agricultural Engineer, Aurélien Deceuninck employed with the French Chambre D’Agriculture. As he explained all of the crops that they were experimenting with, I again brought up the use of cereals for an energy crop if burned directly. Through the translator he quickly waved his finger back and forth at me and stated “that they do not burn food”. I later had this explained to me that this obsession with food crops vs. fuel crops, particularly the use of wheat for anything other than bread, is engrained in the French culture. It rightly stems from the French revolution. Adding to this was the starvation that resulted from the first and second world wars.

I did visit with a French Farmer, Olivier Tissat who was the first farmer in the Somme area to install a grain burning stove. He had purchased an Eastern European built unit for the equivalent of $13000.00 CDN and had installed it on his farm to heat his house, farm maintenance shop and farm livestock building. His was not a commercial unit, but a large residential unit. The French heat mostly by oil fired hot water boiler, so the conversion to cereal was simple. He did replace his existing unit located in his house with the new unit located in a storage shed across the yard. This did facilitate the need for relocating water pipes underground. When I again broached the subject of food vs. fuel, he was quick to agree that you do not burn food in France. However, he was burning the gleanings from the local oat mill. He was only utilizing waste grain.

This theme was again discussed with North American farmers, but to a much lesser extent. This opinion was driven mostly by high commodity prices for corn. It is an issue that each individual must address. Do they wish to produce food, or are they comfortable with producing a food crop used for fuel instead.

Energy Transfer

Biofuel: Fuel (solid, liquid or gaseous) made from renewable resources are referred to as biofuels. Renewable energy sources are those derived from plant materials produced by photosynthesis. Primary sources of biofuels include: agricultural crops and crop residues, residues from food processing industries, livestock manures and deadstock, trees and forestry products, industry residue, and the organic portion of municipal solid waste (MacMillan, B. et al.2008).

Thus we need to take that fuel source and transform it into a product we can use.
The simplest means is to burn the dry material "solid biofuel" like straw in a chamber where we can collect the heat. The next step up the complexity chain is a "liquid biofuel" like biodiesel. This is made by refining the oil extracted from oilseed crops such as soybeans or canola and used in a diesel engine. In some instances pure plant oils can be burned directly in a diesel motor as Rudolph Diesel's first engine ran on straight peanut oil. Ethanol is made by converting starch crops into sugars, which are then fermented and distilled into alcohol. The most complex process involves making cellulosic ethanol. It is ethanol derived from cellulose found in the stalks and leaves of plants or wood. It must first be treated with acids and enzymes to release the sugars from the long chain polysaccharides. The process also requires a huge input of heat.

Climate change is generally accepted to result from the burning of fossil fuels and the release of greenhouse gas emissions like carbon dioxide (CO_2). Biofuels are regarded as "green" and do not contribute to climate change as they are neutral in terms of CO_2 emissions. The burning of biomass fuels merely releases the CO_2 that the plants absorbed over their life spans. In contrast, the combustion of fossil fuels releases large quantities of long-stored CO_2, which contribute directly to global warming. Using biofuels displaces fossil fuels and helps slow the rate of climate change.

Proponents of biofuels will list the advantages when comparing them to fossil fuels as:

- Less toxic to non toxic
- Renewable resource
- Can be grown anywhere crops are grown

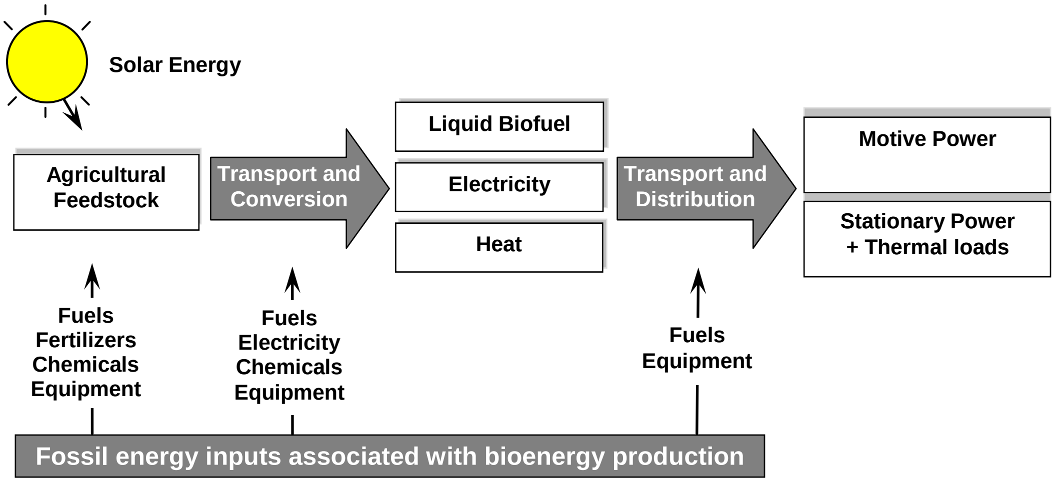
However, we need to understand how the biofuel sources were grown, harvested, processed into an energy source, and transported to the end use (consumer).

What is the "ENERGY BALANCE"?

This is the net energy which is calculated by subtracting all the energy consumed in producing the product – primary production, processing and transport – from the Bioenergy Life Cycle Diagram 1(Main, 2007). The earlier we utilize an agricultural feedstock in the Life Cycle, the lower amount of energy input required.

Diagram 1

Bioenergy Life Cycle



If we compare the energy balance of various biofuels does it make logical sense to highly process some agricultural feedstock for relatively little net gain in energy output? Table 1 (Bourne 2007) provides a general comparison of the energy realized for every one unit of energy consumed to generate a biofuel, the subsequent return in energy output.

Table 1 Energy Balance for various Biofuels

	Energy Output						
	Ethanol			Biodiesel	Solid Fuels		
Energy Input	Corn	Wheat	Sugar beet	Canola	Switch Grass	Cereals	Willow Chips
1.0	1.3	1.5	8.0	2.5	14.0	10.0?	25.0

Discussion: Solid Biofuels

Biomass Combustion:

The primary limiting factor for the use of herbaceous biomass has been the quality of the material in the combustion systems to burn completely. There are two primary elements, potassium and chlorine, that when burnt at high temperatures, vaporize from the feed stocks and generate a corrosive salt formation on the furnace apparatus. When these compounds mix with silica particles they form “clinkers” which cause serious operational issues for the boiler. These hardened masses disrupt airflow impeding combustion, as well as ash removal. In the past this has resulted in the boiler having to be shut down, allowed to cool and have the hard material physically removed by beating with a hammer. However, as the demand for boilers that can utilize biomass has increased, the technology to address this issue has also evolved. The problem has largely been solved by new designs that create a staged combustion. Simplified, the initial temperatures at which the feed stock burns is below the melting point of the ash. The gases are released from the biomass but the chemical components are retained in the ash. The addition of fresh air is limited, helping to reduce the amount of alkali components. Then the gases that remain are heated to a higher temperature with the added component of turbulence for a more complete combustion. The ash is then moved away from the primary burn location on the fuel bed and deposited in an ash bin (Jannasch et al. 2007).

Government Restrictions

Recently Metro Vancouver passed a bylaw that will restrict the particulate emissions from biomass boilers. As a response to rising fuel costs and to avoid British Columbia’s carbon tax the greenhouse industry had installed 26 biomass burning boilers. The new bylaw “Agricultural Waste Control Regulation” will see boilers divided into two categories: those greater than three megawatts and those less than or equal to three megawatts. There will also be a category for boilers under one megawatt. Particulate emissions for farms with small boilers will be 120 milligrams per cubic metre (mg/m^3) and lower limits of 50 mg/m^3 for farms with larger boilers. These would decrease to 25 mg/m^3 for small farm facilities and 20 mg/m^3 for large farms by 2014. Besides initial registration fee and annual fees, biomass boilers will also be required to pay fees based on estimated emissions. That fee is yet to be negotiated (Schmidt 2008).

Residue vs. Fuel

One of the biggest arguments against the potential profitability of energy crops from crop residues is the long term loss in soil quality. “Grain is for the farmer, residue is for the soil” as stated by the renowned Chilean no-tiller Carlos Crovetto. The importance of crop residue is for rebuilding lost organic matter, reducing compaction, improving biological activity, protecting the soil from erosion, and overall improvement in productivity.

A team of Ontario Ministry Agriculture Food & Rural Affairs staff have calculated that 3 tonnes of carbon per year are required to maintain the organic matter content of a hectare

of moldboard-plowed corn soil. The turning over of plowed soils exposes organic matter to atmospheric oxygen where it is oxidized, (in effect burned up). The process is drastically reduced in no-till situations because of limited soil disturbance. It can take as little as three years to effectively burn away most of the 50 to 100 tonnes of humified organic matter in a typical acre of soil. However it may take multi generations to rebuild that same level of organic matter.
But in a potato rotation any proceeding heavy residue rotation crop needs to be thoroughly incorporated (Button 2007).

Straw Biomass

Typical potato rotations across the Maritimes include one and sometimes two cereal crops. The grain is typically directed to the livestock feed industry the straw either chopped at the discharge of the combine and incorporated in the soil when the residue is plowed or the straw remains in stalk length and baled for livestock bedding.

As the livestock industries have changed in recent years, the use and subsequent demand for straw has diminished. Fewer dairy operations bed cattle in tie stalls opting for free stall loose housing and the hog industry has suffered a drastic constriction due to low prices, and limited kill plant facilities.

The concept of burning straw is not new to the biofuel industry. During the late seventies large round bale furnaces were trialed across Canada with one located in Nova Scotia. Jock Peill of Lyndhurst Farms in Canning had imported the technology from Germany. In the first year the furnace used 400 tonnes of straw to dry 1800 tonnes of grain corn and cereals and heat a 260 farrow-to-finish hog unit. This was in direct response to rising fuel energy costs, decreased margins for agricultural commodities and exorbitant interest rates for borrowed capital. He also struggled to incorporate the huge volume of residue that came about from his European approach to growing milling wheat or ICM (Intensive Cereal Management). However, as oil prices plummeted, the economics of this strategy changed and the technology was largely forgotten (Winslow 1980).

Straw Boiler Usage:

Hoake Reeves of Prince Edward Island constructed a single bale unit furnace from a used propane storage tank. A single walled steel tank was wrapped with a water jacket and then insulated. A stud wood frame structure clad with steel was erected around the exterior. The furnace had a hinged full circumference door at on end with an exhaust stack and in air intake port located on the face of the door.

I n the case of this producer there was limited local demand for baled straw as the market was saturated by other farmers, and he did not have a livestock operation that required bedding. Additionally there was on an on farm manufacturing facility of 1115 m^2 that required heating. For both of these reasons, burning of the straw was viewed as a more attractive use then the benefits of building soil organic matter.

Costs:

Although straw may be viewed as free, as the revenue from the cereal crop is generated from the sale of grain, there are costs associated with the burning of the straw.

- There is an energy requirement for harvesting, transporting and storage of the crop. Round bail harvesting of straw and hauling from the field is generally agreed to be restricted to a distance of 80 km.

- Storage from weather is viewed as necessary as extra moisture must be driven from the straw in the process of burning. To drive the moisture that is contained within a bale requires heat energy. Thus any extra moisture reduces the heating value.

- Requires equipment to load the unit. Round bale furnaces / boilers require a dedicated piece of equipment for use once or twice a day. This is not an issue if the furnace is located at or near the farm.

- Loading and ash removal interrupt the heat generation. Current furnace / boiler configurations require an opening large enough to accommodate a round bale circumference. Thus the heating load is variable and thus requires a back up system to cover the interruption as well as supply supplemental heat to the water lines in the downtime.

- The unit needs tending by an operator, as the process is difficult to automate. General time to clean out ash, load a fresh bale(s) and relight requires an hour per reload, or minimum two hours per day.

- Emissions from the unit will become a factor to consider. No emission control devices were added to the unit viewed. The particulate matter leaving the stack was noticeable and the surrounding area did have a soot component on surfaces. Site location will require careful consideration. If this was near a greenhouse facility light transfer through the glass / plastic covering could be reduced.

Coppice Willow

Lionel Hill south of Birmingham in Central England has been experimenting with willow as a biomass heating source since 1978. At that time, as a result of the current energy crisis he began looking for alternative heating options for his house, farm buildings and rental properties. He began by looking at utilizing crops or crop residues that he grew on farm. This led him to conduct an in-depth review of burning wheat straw. He weighed the difficult ties of handling big bales and the lack of furnace boilers to handle the straw and directed his attention to willow.

He visited the industry leaders, the Swedes, and then shortly followed this by planting his own plots. He originally looked at both poplar varieties and willow. The poplar varieties required seven plus years before cutting and would not regenerate as quickly. For these reason he moved to willow.

Cultural Practices:

- The willow is planted in rows similar to corn. He uses a double row planting configuration with a 0.5 m between plants, 0.75 m between rows and 1.5 m between the next rows. Planting can begin in the spring as soon as the soil is warm enough for other crops. As the plant will regenerate from the nodes located on the stalk, Lionel has modified a vegetable planter to take a 1.2 m length of willow and cut into quarters. Of this material two thirds of the length is planted under ground with the remainder above the soil surface. He has found the he has the best luck with rooting by using one year old material.

- Inputs are limited to an application of herbicide in the spring following planting. This is necessary to allow the billets to root and send out new shoots. Once the plants are established they will out compete the weeds for light and water. No fertilizer is required and the leaf litter that is generated on a yearly basis will sustain the crop through its life span. He has some plots that have been in production since 1992.

- Harvest can not begin until the plant is dormant. In central England this is not possible until late November. By this point the leaves have fallen and reduced the moisture content of the biomass at chopping. Harvest is completed using a standard forage harvester that has the header modified to match the rows of willow. Standard chip size is similar for corn silage of 2.5 cm. Lionel liked the forage header cut as it provided a consistent chip size. Generally he did not harvest before the crop had reach three years of maturity.

- Harvest scheduling provided a unique opportunity. Fields were harvested on thirds. The idea was to only harvest one third of each field in a year. This provided cover to the remaining two thirds of the field. Should a field or variety no provide adequate growth he used a standard rotovator to chew up the root crown mass.

- Yield is variety and climate specific. In his location he was achieving up to 20 tonnes per ha which he felt was returning up to £50. He equated this to a 1.6 ha field being able to generate enough heat for a standard four bedroom house over a three year harvest period.

Willow Boiler Usage:

- Chips storage is in open ended sheds with vented sides. Height of the pile was limited to 3 m more to the fact that he was utilizing an existing shed. Lionel has never had an issue with heating resulting in a fire from spontaneous combustion. He felt the secret was dormant plants that resulted in a chip with approximately 50% moisture content and allowed to dry down to 25% moisture in 3 to 4 months. Also important was for adequate ability for heat removal as the chips cure in storage. The shed allowed for heat to adequately disperse through the top of the pile.

- Hot water boilers were located near the chip storage. He had two units in place which allowed for one to be down for ash removal while the other was generating heat. Chips were augured in from a hopper system that required daily filling. Originally coal fired boilers, they had been converted to gas and then to wood. Units were over 30 years old and been salvaged form institutional settings. To address the labor requirements and the interruption of operation due to ash removal, he was installing a single boiler with auto ash removal. It also included a large hopper for a 12 – 15 day storage reducing the daily need to supply chips.

Environmental Benefits

- Coppiced willow provides a habitat for wildlife. As harvest is limited to late fall, bird nesting and rearing is not interrupted compared with grass silage production.

- Willow is a water loving plant and will tolerate wet soil conditions that generally limit other crop options. The lateral root system provides a base that will support harvesting equipment. Thus marginal land that would necessitate capital investment of tile drainage, may forego that requirement. Additionally, the low input needs of a single herbicide application to produce a crop make it ideal for sensitive areas / riparian zones. Note: provided adequate drift management measures are implemented.

- Willow provides permanent cover for the soil preventing soil erosion. However, it must be recognized that late fall harvesting often occurs in higher rainfall periods when soils may be saturated. This can be alleviated by waiting for a frost event, when the ground is slightly frozen, but not so cold as to impair the chopping of the wood.

- In the case of Europe, regional planning requirements for development for housing complex is viewed as beneficial with a green energy source for heating. The set aside programs can be combined with energy tax credits as a partial subsidize for cost of infrastructure.

- The physical stature of the crop provides a barrier for activities that occur off site from the field. This includes noise abatement, as well as line of sight disruption.

He has set up a nursery on his farm specifically to test new varieties. Most of his varieties are imported from Sweden out of their research programs. He reviews for yearly growth rates, drought tolerance, re-growth following harvest and has varieties that have growth rates in excess of 4 m per season. As a side benefit, the varieties had differing colors from yellow to red. This material was in high demand buy the local craft college for design. However the volume of usage was low.

Limitations:

Although Lionel had been farming willow for more than twenty years he had not reached the level of integration into the local economy that he felt it could achieve. His reasoning was that a critical mass for utilization had not been set by the local economy. He felt that other area farmers would not make the switch to willow until an institutional customer was on side to burn the fuel. However, this had not occurred as no intuitional customer was prepared for the cost to retro fit of their existing heating infrastructure as sure supply of raw biomass was available. His desire was to work toward a village setting a central heating plant for the local residents and then a cooperative of growers taking a portion of there land holdings for a permanent willow crop. He had set a limitation of 32 km as the outer boundary for delivery to a boiler, after that point the cartage cost became greater than the energy value to be gained.

Other Willow Producers:

John Gilliland took the energy portion an additional step in the equation and added disposal of sanitary sewage tipping fees. The willow plant will use the nutrients contained in the sewage and act as a filter. The nutrients reduce the period of wait between cuttings to two years. Although the volume of biomass generated is less than in the low input system the tipping fees were able to more than offset.

John Strawson had switched a large portion of his family's 1200 ha arable farm to willow, to eliminate the volatility in grain prices. He did have a local advantage in that a majority of the land holdings were located around a large coal fired electrical power generating station. The willow was mixed with the coal as an off set for CO_2 emissions. John had also taken a different approach to harvest. He located a sugar cane harvester and cut the willow into 0.5 m long billets. The billets could then be stored out side in a loose configuration. The crisscross configuration then allowed for easy airflow which greatly reduced the natural process of biological breakdown. He felt that this allowed him to maintain more of the heating value. When the electrical plant required a load of chips he would then chip the billets for delivery "just in time".

Applicability for a potato rotation:

- The addition of coppiced willow into a 3 year potato rotation is not possible due to the 3 year stand establishment period. However, there is an opportunity to add plantings to riparian buffer areas, marginal ground that has a high water table, and areas that are not suitable to row crops.

- Economic constraints must be addresses. Either an on farm requirement for heat or a near by institutional / industrial client needs to be secured with a commitment to long term contract. This is necessary to address the three year stand establishment before a monetary return can be realized.

- To off set infrastructure costs of planting and harvesting equipment a cooperative venture would reduce the risk associated with one farmer investing in specialized equipment.

Switch Grass

I met with Don Nott of Western Ontario. He has the largest sowing of switch grass in Eastern Canada at nearly 140 ha. Nott and his family farmed 4850 ha of cash crops near Clinton ON. At the farthest he was traveling 110 km. for some farmland. Commodity prices were falling and his cost of production was increasing beyond his returns so he sold off the majority of his farm equipment and set most of his land into long term leases. Don however felt that the market for switch grass as a pellet substitute to traditional fossil fuel could only grow. He has subsequently been testing the field production and processing of pellets from purchased baled switch grass.

Switch grass is a perennial grass native to the mid west area of North America and traditionally grows in wet areas and along river banks. It can reach up to eight feet in height in southern Ontario, and still higher in the southern US. The root mass generated is similar in depth in the soil.

Cultural Practices:

- The crop can be sown as a direct seeded crop by itself or under-seeded to oats. The direct seeding can be no till or drilled into a shallow cultivation. Some work has been done with loose seeding (broad cast) and followed with a packer. The seed requires a firm seed bed. Don has had the best luck with under-seeding. He purchased seed from Pennsylvania, “Caven Rock” that was best suited to his heat units.

- Not all seed germinates in the first year. This gives an uneven appearance. Particularly weed establishment by other grasses like foxtail will appear most prevalent. Once the crop establishes it will out compete the weeds for nutrients, light and water. However, the Achilles’ heel of the crop is establishment. Once firmly growing, a stand can last for more than twenty years.

- Fertility requirements need to meet the nitrogen demand of the crop that is removed. Sixty seven kg of nitrogen per hectare will sustain a twenty one tonne crop per hectare.

- There is no harvestable crop the first year, and only a seventy percent crop the next year. A fully productive crop requires three years of growth.

- A killing frost is required before the crop is cut. A mower conditioner will cut the stems but the dense nature of the stalk will dull the cutting blades. The crop is then allowed to dry in a windrow before being bailed. However, recent research is suggesting that if the crop is allowed to weather until the following spring that a portion of the potassium and chlorine will leach out and be less of a problem at time of burning (Bailey et al. 2007).

- However, other experience with the crop suggests that a 20 tonne crop is excessive for most harvesting equipment and is best handled with two cuttings throughout the season. Stalk density can also cause harvesting issues of punctured tires. Thus a twice per season harvest is a solution.

There is the potential for the crop as a revenue generator with carbon credits. Harvesting the crop can generate emissions, but up to 93% of the carbon is retained in the loop. It is stored mainly in the roots. Anticipated payments could be up to 10.00 dollars per tonne of CO_2 tied up in the eight tones of root system per hectare. That could equate up to $120/ha. However the system for carbon credit trading is in its infancy and is met with skepticism by most farmers (Jannasch et al. 2007).

Pellet Production:

The pelleting process involves the following steps: (As described by Sampson et al. 2007)

- Handling of the harvested switch grass bale should be treated the same as high quality livestock feed. The bales need to be removed from the field location quickly following harvest to prevent moisture from accumulating on the surface of the bale. Consistent moisture levels across the bales are necessary to produce a uniform pellet. Damp material on the bale results from outside storage, bales that touch each other and contact with the ground.
- Bale breaking is required to chop forage fibers to a suitable length for drying, normally 2.5 cm to 10 cm in length. A livestock hay tub grinder can be used. Square bales process more easily and quicker than round bales. The square bale fibers are shorter and the bale falls apart into flakes vs. the full length, wrapped fiber of the round bale. This affects processing throughput and processing costs.
- The feed stock moisture needs to be dried to a consistent 10 – 12%. Often field dried bale moisture will be between 12 – 20%. This is accomplished by fine grinding using a rolling drum dryer. A portion of the processed switch grass can be added back into the drying process as the fuel source fro the dryer. The dried

material then must be put through a hammer mill to reduce the size of the feedstock. This process also allows for a binding agent to be added pre pellet forming.

- The ground feedstock is fed into a pelleting chamber where rollers force the material through holes on the inside of the die. As pellets are extruded, adjustable knives cut the pellets off to the desired length on the outside of the die. Generally accepted diameter for wood pellets would be 0.64 cm.
- During the pellet forming process steam can be added which activates any natural binders in the switch grass. Water can be substituted, but the binding effect is less pronounced.
- The compression forces generate heat and pellets leave the die at a high temperature. They then need to be cooled or they will “sweat”. A wet pellet then swells and looses the tight compressed effect and fines are created. Additionally, fines happen from the cutting process. A screen is used to separate this material which is most efficiently added back into the forming process.
- Handling and storage is similar to cereals or oilseeds. Pellets are easily moved by auger or pneumatically. Regular grain storage tanks are utilized. Large U-sacs provide a convenient method of storage yet are relatively easily handled by a forklift, skid steer or front end loader on a tractor.

The process of pellet formation is the same for various feed stocks. I viewed the exact same process being used for chicken litter. A portion of the pellets were used as the fuel source for drying the litter direct from the barn. Although the chicken manure pellet was directed toward a high end organic input market through the chain stores, excess pellets were used as a fuel source, particularly as fuel oil prices climbed.

I did attend a conference on pelleting agricultural and forestry material to gain an understanding of the feasibility of incorporating on farm. Initial start up costs is around 2.5 million dollars (CDN) for a 2 tonne per hour line. However, pellet units from China have drastically reduced this cost to less the one and ¾ million dollars. The challenge is competing against the wood pellet market.

- The market is highly competitive price wise – is influenced by the demand along the US Eastern seaboard. Pellets are stockpiled in preparation for the impending heating season. If demand is lessened by a warmer then expected winter, prices plummet. It functions the same as other commodity markets.

- The consumer has high expectations based on experience with a premium white wood pellet, including lack of fines, burn time and odor.

- As with all fuel sources, consumers will switch based on cost. If oil is cheaper they will switch back to operating their oil furnace or electric. They are not tied to one fuel option.

Additionally I visited a die manufacturer in southern Ontario. Their main market is the feed mill industry for the manufacture of livestock feed. The silica content of switch grass is abrasive and reduces the life expectancy of the equipment.

Applicability for a potato rotation:

- The addition of switch grass into a 3 year potato rotation is limited due to the stand establishment issue and that it is a multi year perennial crop. However, there is an opportunity to add plantings to riparian buffer areas, marginal ground, and areas that require a long term “rest” from traditional row crop agriculture.

- No additional equipment is required as long as there is a livestock feed production component. The farm equipment utilized to seed forages/cereals, and harvest grass for baled hay will adequately handle the crop requirements. Generally round bales or large square bales increase efficiency.

- Two options for utilizing the baled crop need to be considered. Either the material is burned directly in its present harvested form of a bale, or requires further processing into a pellet. The simplest option is to direct burn to supply heating requirements for intensive sectors like greenhouses or livestock containment operations for hogs. If pellet production is pursued, it is best viewed as a value added stand alone business. Numerous other factors must then be considered if competing with traditional wood pellets (see appendix 1).

Cereals & Cereal By-products:

As I began to investigate alternative energy crops a local potato farmer approached me about burning wheat. At this point I had no knowledge about cereals as a fuel source. He explained how he had dumped 1100 tonne of the preceding year’s crop for Fusarium contamination. He was regretting that he could have used it to heat his farm shop / potato packing facilities. This conversation put me onto the bulk of my Nuffield study.

The 2005 wheat crop in New Brunswick was the third year in a row the fusarium head blight (FHB) had been a serious disease problem in wheat and barley. It is caused primarily by *Fusarium graminearum*. It occurs on a wide range of hosts including wheat, barley, oats, corn and grasses. The occurrence of FHB is dependent on presence of the pathogen and favorable environmental conditions from the flowering stage onwards. Effects of FHB include yield losses, shriveled and light weight kernels and mycotoxin contamination. The production of these toxic substances can adversely affect animals, including feed refusal, vomiting, poor weight gain and immunosuppression. The guidelines for the most common vomitoxin, deoxynivalenol (DON) is 1 part per million (ppm) for swine to 5 ppm for cattle. The grower reported levels above 7 ppm. His entire crop was destroyed (see Picture 1).

Picture 1

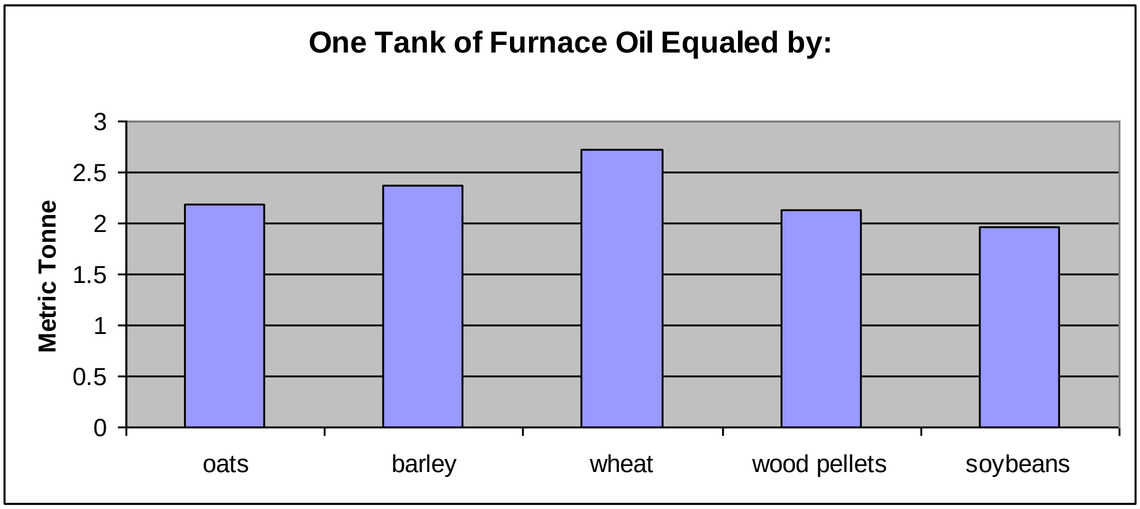
Cereal by-products have already made a transition into the energy supply chain in Ontario. Don Nott is also behind this initiative. He maintained his grain handling terminal for processing oat hulls and pin oats for the horse feed industry. He buys the oat by-products from the breakfast cereal processing markets in Ontario and New York State. He contracted the oat by-products pelleting with a local feed mill. However he never considered the crop residue as a form of fuel until approached by the greenhouse industry. The “densified” pellet will burn in most pellet stoves and boilers. Heat value is 7600 BTU/lb and a greenhouse grower can expect to use an average of 0.8 tonne a day – spread over 12 months – to heat an acre of glass in southern Ontario. At the time of our discussion he was charging a $125.00 dollars a tonne or $7.50/gigajoule. This was two dollars less than the spot price for natural gas (Stoneman 2006).

In Ontario, two of the greenhouse operators I visited were operating heating systems burning this cereal by-product. Typical set up involved a grain concentrate tank of approximately 10-20 tonne on the exterior of the greenhouse. An auger transferred the pellets to a hopper that then metered the fuel into the combustion chamber of the furnace. Temperatures can reach between 650° to 2,000° Celsius. Water flows at a rate of 80 litres a minute through a series of tubes above the combustion chamber, absorbing the heat. Water temperature typically runs between 27° and 36°C depending on heating requirements, although higher temperatures can go higher (Harrison 2006b).

Increased oil prices made cereals and attractive alternative just a few months ago, but with the price of crude dropping near 50$ a barrel oil again looks attractive. Also cereal prices have also started to decline from their record setting highs. When this study was initiated, cereals had had three consecutive years of poor prices with returns below the price of production then followed by huge increases. Where will revenues go is a question, but it is fair to say that following the current economic times that oil will recover and climb again.

The heating value of various cereal crops and wood pellets and soybeans for comparison is found in Chart 1 (Proctor 2007).

Chart 1



Heating comparisons have shown that a bushel of cereals can supply the heating requirements of a 140 m^2 house on a daily basis. It is dependent of the efficiency of the boiler as well.

A more complex combustion-air distribution system is needed for grain than for pellets, corn or wood chips, as the grain packs more tightly and restricts air movement. New combustion chamber design has addressed this specifically with a pot and no grate system. Thus not all pellet / corn burning boilers are suitable for other biomass fuels without substantial changes. Additionally new boilers are constructed of materials that are unaffected by the higher chlorine content of grain. It is possible to retrofit boilers but this becomes difficult when accounting for the need for corrosion-resistant materials. An unpleasant odor is sometimes mentioned as a problem with burning grain. However, this only occurs when the flame is restricted and the grain smolders. The best way to overcome this problem is to reduce low-load operation by under sizing the boiler and storing heat in water storage tanks that are then recirculated during the night time when demand load is greatest.

Burning the kernel of various cereal crops is considered as Carbon Neutral. Emissions from burning cereals are lower than with wood for Carbon monoxide (CO). A more serious problem is the higher content of nitrogen in some grain, which leads to high Nitrous oxide (NO_X) emissions. This is of particular concern in Europe due to restrictions. But as in the case of B.C. these restrictions are coming. The Engineer in France had the answer to this issue, burn oats. The lower the protein level, the lower the nitrogen content of the kernel and the lower the resulting gas emission.

There is a need for an outlet for diseased or lower quality grain. Practical applications for heat uses for grain are drying of other crops. Grain drying would take on average about

25 kg of fuel grain per tonne of grain dried or 2.5% of the crop. The difficulty in this application is that the drying period is a short term. Secondly, supplying an institutional boiler at a hospital or school provides an alternative that is not seasonally dependent.

While touring a farm utilizing a cereal burning boiler, we looked over the grain storage structure located outside of the farm building. The farmer had recently filled the grain tank that fed the boiler, and had spilled a bushel on the ground. He was reluctant for me to see this as he took pride in maintaining a clean farm yard. However, spilled grain is easily cleaned up vs. oil that would require an environmental response.

The future is a system that I saw at Harper Adams University in England, where a boiler manufacturer set up a Combined Heat and Power (CHP) unit. The boiler was using feedstock from wood waste when I witnessed it in operation, but was capable of burning multiple types of biomass feedstock. The boiler was supplying the University with hot water for space heating. However, the steam was first directed through a heat exchanger located above the firing unit. Water located in the heat exchanger was heated into steam where it was then driven through a turbine to generate electricity. The generation of electricity is currently at a ratio of 2 to 1, i.e. twice as much heat is generated to power. This type of unit is costly at around 750,000.00 $CDN for the boiler alone.

Applicability in a potato rotation:

- Cereals are already an important component in a potato rotation.
- There is no new equipment or infrastructure to purchase.
- Farmers are experienced with cereal production and no learning curve is necessary for cultural practices of production
- Farmers will need to consider the value chain for grain sales. This could be on farm usage to dry other crops or a longer term contract with a larger energy consumer like a greenhouse.

Factors to Consider With Biomass

All of the farmers / greenhouses growers had a number of common issues:

- A boiler system needed to be flexible in the biomass feedstocks that it could handle. They did not wish to be married to one fuel source. This was due to the volatility in price of various commodities. If corn was in short supply but a lot of diseased barley was available they wanted that ability to switch feedstocks to take advantage on price savings. According to Russ Carroll “you can always burn something else and use the lowest price fuel” (Harrison 2006a).

- Security of supply. In the case of one operator in Prince Edward Island who set up a series of saw dust burners to heat his greenhouse, when his supply of sawdust was directed to a more profitable market by his supplier, he was forced to look for alternatives. He was forced to switch to barley but because of his boilers combustion chamber / air supply he was limited to a 50 / 50 blend of saw dust grain.

- These systems often have issues with start up and require a learning curve; operators need to be prepared to devote time and physical energy to make the system work. The fuels sources vary in moisture content and their efficiency will change. Obtaining a consistent product to burn, free of foreign material (metal and rocks) with a similar particle size improves efficiency.

- Storage and handling systems are an important component. Source material needs protecting from the weather. The more automation in handling will increase cost but may result in greater success due to operator satisfaction.

- CO_2 enrichment of the greenhouse is often from the flue gases of a natural gas fired boiler. These gases are added back into the greenhouse environment in winter to compensate for the lack of external air brought into the structure. Decreased CO_2 will result in poor plant development and reduced marketability of the crop. Little to no CO_2 is available from biomass sources and subsequently will require supplemental pure CO_2 addition.

- Ash from the burning of biomass must be considered. The high potassium content of wheat and barley and silicon of oats increases their ash content (2.7% wheat, 3% barley, 3.5% oats) above the willow (2%) but below that of wheat straw (4.5%). Automatic ash removal systems are available and can be augured away from the boiler for disposal.

Research Project: Reduced input Cereal Production

Upon returning from the Global Focus Program my employer at the time, McCain Foods (Canada), requested that I incorporate a research trial on where I thought my studies might lead. The trial was conducted at the McCain Research Farm in Florenceville NB over a three year period.

Introduction:

Having spent time reviewing cereals as an energy crop, I wanted to look at strictly producing a crop with the lowest cost of production. I was not concerned about end quality, such as obtaining a desired marketable protein content. Additionally, I was not concerned about losses from disease or contamination by weed seeds, as the desired outcome was to burn the crop as an energy source. It was not a purely scientific trial in a replicated format with a control, but more a demonstration plot to provide an indication of results. Standard cultural practices include two tillage passes with a harrow, added fertility with a triple blend, in excess of 100lb of nitrogen (N) and a weed herbicide when intensively managed.

To reduce input costs the following cultural practices were followed:

- One pass tillage and sowing of the crop. This was accomplished by using a tillage harrow that combines a row of disc coulters to cut any residue trash, a section of viber shank teeth to work the soil to a depth of 5 inches and a section of spike tooth teeth to level the seed bed.
- The seed drill was attached to the rear of the harrow and drilled the seed directly following tillage.
- A roller was attached following the drill to provide better seed to soil contact.
- 50 lbs of ammonium nitrate fertilizer was drilled in a band at sowing.
- No herbicide or fungicide was applied.
- Increased seeding rate to 115lbs/ac.

Observations:

- One pass tillage was not adequate where previous vehicle traffic compacted the soil. As this was a research farm with replicated plots for potato experiments in the proceeding crop noticeable areas showed stunted growth the first season. In subsequent years, the truck paths between plots were given an additional tillage pass before sowing the oats. Practical application means that any truck routes from potato harvest must be ripped out to reduce compaction.
- The key to having a productive cereal crop is to capture solar energy and turning it into a kernel. Think of every hectare as a 43560 ft^2 solar collector. To maximize photosynthesis, a solid stand is needed, that means no bare soil. Bare soil results in lost productivity and provides an opportunity for weed invasion. This required a higher seeding rate and a slight increase in cost.
- When combining tillage and seeding practices, the overall length of equipment can become an obstruction to efficient field operation. This is a minor issue, but operators may need to modify their turning practices near field edges to compensate for the increased length of equipment behind the tractor.

Results:

Table 2 Three Year Oat Yield and Quality

YEAR	Plot Size ac	Test Weight kg/hl	Total Yield kg	Yield lb/ac	Moisture	BTU/lb (dry wt basis)	Ash %	Nitrogen %
2006	1.97	51.0	2850	3170.6	13.42	8270	2.17	1.86
2007	3.44	53.7	5740	3675.3	13.11	8166	2.65	1.83
2008	3.19	46.1	3470	2394.0	17.17	8198	2.54	1.74
Wt Avg		40 lb/ac		77 bu/ac				

Note: for this section results are reported in imperial measurements.

Discussion:

Across the three years, one pass tillage was adequate once the previous season heavy traffic areas were accounted for with an additional tillage pass. The oat crop is an excellent scavenger of carryover nutrients. Soils growing potatoes are generally high in phosphorus and potassium levels, and can carry a small residue of nitrogen. This is season dependent and can not be relied upon from year to year. Thus 17lbs of actual N was drilled with the seed to provide adequate fertility. No noticeable N deficiency was detected in plant growth or leaf color. This also provided an additional benefit that excessive growth did not result in lodging of the crop.

Yield results in the third year were reduced due to an infestation of European corn borer (ECB) larvae. This insect has emerged from a relatively low level secondary pest to a primary pest requiring treatment in the potato crop. It is non selective in its host range and will utilize various plant species from corn to cattails to second year apple shoot growth. The insect larvae bore an entry point in the stem, eat their way through the internal cell structure and effectively stop the transfer of nutrients and water to the developing kernel effectively producing a blind seed.

The three year average of 77 bu/ac for total yield (see table 2) was well above the provincial average over the past seven years at 58 bu/ac (see appendix 2). It must be noted that oats do not receive the same level of attention as a cash crop of wheat and barley and subsequently are planted with lower fertility on soils described as poorer.

Additionally the samples were tested for energy value. The British Thermal Units (btu) were similar to those reported in the literature. For comparison wood pellets will range around 7000, soybeans around 8000, corn around 8800 and grains at 6500 - 7200 btu/lb at normal moisture content. The dry weight basis for oats when corrected to a 13% moisture content had an average value slightly lower than 7200 btu/lb.

Oats were sold to the local feed mill. They were graded as a No 3 Canada Oat dark in color, and could not be sold into the premium horse feed market.

The input costs were calculated at $72.00 per acre for the first year, $75.00 the second year and $92.00 the final year. This is in comparison to a traditional cost regime of $120.00 per acre for the first two years and $148.00 in the last year. The last year costs reflect increases in fertilizer and fuel. Note: that costs are dependent on many factors and these represent and average of those that could be expected. Actual costs will depend on an individual case bases, on multiple factors. Subsequently, the sale price for grain commodities has fluctuated greatly and has seen lows of less than $100.00 per tonne to more than $225.00 per tonne, local market. Any comparison of cost vs. revenue must be completed on a spot day basis, and readjusted when projecting for future considerations. For this discussion the average dollar savings is calculated at $50.00 per acre savings.

Conclusion:

Reduced inputs, including reduced tillage, fertility and weed control when seeding oats in rotation with potatoes does not negatively effect yield. Tillage practices can be modified with better equipment design to reduce passes. Additional passes in the field can further be reduced by combining the practices of tillage and seeding. The oat crop can utilize the residual nitrogen from the previous crop in combination with a reduced amount of supplemental N at planting. Higher seeding rates are needed in combination with accurate seeding, leaving no bare ground for weed establishment.

Conclusion

There are many options for biofuel crops as an energy source. However, not all are easily incorporated into a potato rotation. Both coppiced willow and switch grass have many qualities that make them attractive components of a farming system, but they will not fit with a potato rotation because they are long term perennial crops. They could be included in field areas not suitable for potatoes.

The burning of cereals, particularly oats is where we can make gains for farmers. The crop can easily be incorporated into a potato rotation. By changing cultural practices and by following potatoes the cost of production can be reduced.

All options for a biofuel crop require more attention in use than standard forms of fossil fuels. Choices by end users need to consider the variability in product. This includes BTU value, moisture content which directly affects efficiency, convenience of handling systems and operator satisfaction. Most forms of solid biofuels are high in bulk density which limits the economics of transport. Boiler system flexibility to handle various forms of biofuels is advantages.

Ultimately the price of a barrel of oil will dictate if a biofuel is economically feasible.

Recommendations

I believe that there is an opportunity for many local farmers to utilize cereals as an energy source on farm:

- It may be a simple use of the energy for space heating load of farm buildings in the winter, but may have advanced uses in drying of other crops like corn or roasting soybeans.
- Production of energy on-farm can be utilized in the marketing of farm products as "local". It should be viewed as a piece of the equation in reducing the carbon footprint in agricultural production.
- There is an opportunity for a rural community to look at the installation of a unit for a community center, rink, or larger projects of heating a school or hospital.
- The true possibility is to combine the burning of cereals with co-generation of electricity. This will require an outlet for the heat, as well as for electricity. Such a demand exists with greenhouse producers, which have a high demand load for heat, as well as the continued increase of supplemental lighting in the short day light periods of winter.
- There is an opportunity to market grain burning stoves to residential customers and supply them with their fuel.

Declaration

All the views and opinions expressed in this report are entirely my own and do not necessarily represent the views of Nuffield Canada or my sponsors.

Eric F Ritchie
197 Greenfield Rd
Greenfield NB
Canada
E7L 3E8

1 506 392 6906 home
ritchies@nbnet.nb.ca

References

Bailey S., Samson R., and Ho Lem C. 2007 Biomass resource options: creating a bioheat supply for the Canadian greenhouse industry. Resource Efficient Agricultural Production – Canada REAP website www.reap-canada.com Accessed Mar 2008.

Bourne J. Jr. 2007 Biofuels: Green Dreams. National Geographic October 2007.

Button, T. 2007 Cheap biofuel feedstocks take a toll on soil health. The New Farm www.newfarm.org/features/2007/0907/biofuels/button Accessed Sept 2007.

Doan R. 1980 Man with a vision. CBC Television, Country Canada Episode March 1980. Accessed Nov 2006.

Greydanus J. 2006 Innovative Energy Sources. Canadian Greenhouse Conference Toronto ON September 2006. Correspondence with author. Accessed Oct 2006.

Harrison D. 2006a Alternative fuel search includes coal, corn… & oats. Greenhouse Canada Magazine April 2006 www.greenhousecanada.com/content/view/1016/83/

Harrison D. 2006b Cut-flower grower targets a niche market. Greenhouse Canada Magazine May 2006 www.greenhousecanada.com/content/view/1005/38

Jannasch R., Quan Y., Sampson R. 2007 A process and energy analysis of palletizing Switchgrass. Resource Efficient Agricultural Production – Canada REAP website www.reap-canada.com Accessed Sept 2007.

Main M. 2007 Pellet fuels from agricultural residues. Making Pellets and Briquettes from Wood and Agricultural Residue Conference Fredericton NB March 2007. www.wstc.unbf.ca/documents/AgresiduepelletsMMain.pdf Accessed Jun 2007.

MacMillian, B. 2008 Final Report. Environmental and renewable Industries Committee (ERIC) www.gov.pe.ca/photos/original/dev_ericfinal.pdf Accessed Mar 2008.

Proctor W. 2007 Replacing petroleum with biomass for heating on farms. PEI ADAPT Council final report. Correspondence with author. Accessed Aug 2007.

Samson R., Jannasch R., Adams T., and Ho Lem C. 2007 Grass Biofuel Pellets: An ecological response to North America's energy concerns. Resource Efficient Agricultural Production – Canada REAP website www.reap-canada.com Accessed Sept 2007.

Scott, P. 2008 New Brunswick Provincial Yearly Seeded/Harvested Acreage and Yields for Cereals and Oil Seed Crops. Correspondence with author. Accessed Nov 2008.

Stoneman, D. 2006 Bioenergy, The crop that could save the Ontario Farm. Better Farming Magazine Dec 2006. www.betterfarming.com/2006/bf-dec06/cover.htm Accessed Dec 2006.

Schmidt, M. 2008 British Columbia greenhouses battle emissions controls. Farm Credit Canada AgriSuccess Magazine August 2008 www.fcc-fac.ca/newsletters/en/express/articles/20080101_e.asp

Winslow, G. 1980 Burning Straw. Country Guide Magazine March 1980

Appendix 1

Standard Wood Pellet Criteria: American Pellet Fuel Institute
Fuel Type: Residential fuel
Heat content: Minimum 8200 BTU/lb.
Bulk Density: Minimum 40 lb/ft^3
Moisture Content: Maximum 8%
Ash Content: Maximum 1%
Size Restriction: ¼" to 3/8" diameter and Maximum length 1.5"
Fines: Maximum 1% through 1/8th" screen

One tonne of switch grass is equal to:
18 gigajoules of energy
Or equivalent to 459m^3 of natural gas
486 litres of fuel oil
702 litres of propane
4986 kW of electricity

Appendix 2

Table 3 New Brunswick Provincial Yield for Cereal and Oil Seed Crops

	2002 yield bu/ac	2003 yield bu/ac	2004 yield bu/ac	2005 yield bu/ac	2006 yield bu/ac	2007 yield bu/ac	2008 Yield bu/ac
spring wheat	59	39	45	50	35	47	53
oats	73	65	66	62	40	46	52
barley	69	61	58	66	40	64	51
corn	76	84	100	106	112	118	na
canola	na	na	na	32	36	32	33

Appendix 3

Combustion Technology Suppliers

(Neither Nuffield Canada nor the author of this publication endorse any of the products listed here. It is intended as a sample, not a comprehensive list of equipment suppliers.)

Blue Flame Stoker www.blueflamestoker.com Box 285, Headingley, MB R4J 1C1;
Tel.:204 694 2398; Fax: 204 697 7535; E-mail: info@blueflamestoker.com
Models from 800kw to 3500kw

Central Boiler www.maximheat.com 20502 106th Street Greenbush, MN 56726;
Tel.: 800 248 4681
Residential Models
Regional Dealer Network – i.e.

Decker Brand Boilers www.deckerbrand.com General Delivery, Decker, MB, R0M 0K0 Tel.:204 764 2861; Fax: 204 764 2594; E-mail: Clarence@dekkerbrand.com
Models from 44kw to 1025kw
Regional Dealer Network – i.e. *Innovative Combustion Ltd* 285929 Airport Road. Norwich ON N0J 1P0 Tel.: 519 468 6466 www.innovativecombustion.ca

Grove Wood Heat grovewoodheat@pei.sympatico.ca 935 Pleasant Grove Rd., York, PE C0A 1P0 Tel., 902 672 2090
Models from 25kw to 250kw

Harman Stove Company www.harmanstoves.com 352 Mountain House Road, Halifax, PA, 17032
Regional Dealer Network – i.e. *Pete's Hearth & Cottage* 250 Water Street Summerside, Tel.: 902 436 4225
Residential Model

Pro-Fab Industries Inc www.profab.org Box 112, Arborg, MB, R0C 0A0 Tel.: 888 933 4440; E-mail: grant.cairns@profab.org
Models from 220kw to 740kw
Regional Dealer Network – *H C Heating & Supplies* 1168 Northfield Road, Upper Kennetcock, NS B0N 2L0 Tel.: 902 369 2999

Pellagri Energy 434 St. Patricks Road, RR #1 Hunter River, PE C0A 1N0
Tel.: 902 621 0549
Residential Model

Year - A – Round Corporation www.year-a-round.com Box 2075 Mankato, MN 56002-2075
Tel.: 800 418 9390
Regional Dealer Network - *Atlantic Grain Furnaces* 447 Blue Shank Road, Wilmot Valley. PE C1N 4J9 Tel., 902 436 5866

Pelleting Technology

Dorssers Inc. Box 940 Blenheim, ON N0P 1A0 Tel.: 519 676 8113; E-mail chris@dorssers.com
Pellet Mill Dies, Roll Shells & Roll Parts

Pellet Systems International Inc. www.pelletsystems.com 10B Pinder Road, Box 1284 Nackawic, NB E6G 1W3 Tel.: 506 575 2231 E-mail lklippai@pelletsystems.com
Models from 2 to 10 tonne / hr