Evaluation of Farm Scaled Willow Harvesting Techniques for PEI

PE 259 CP

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1. Introduction:

Growing concern over the rising and extreme fluctuations in the cost of fossil based fuels has resulted in increased interest in renewable energy sources. The agriculture industry is heavily impacted by the rising cost of energy and is recognized by the Government of PEI as potentially playing an important role in contributing to viable sources of renewable energy.

In January, 2008 the provincial government's Environmental and Renewable Industries Committee (ERIC) released its final report which states that "agricultural feed stocks, including established and emerging (i.e. switch grass and short rotation coppicing) could be further developed provided market demand is sufficient". Further, it recommends that the provincial Department of Agriculture "develop an agricultural policy regarding the development of an agriculture based biofuels industry".

More recently, in January of 2009, The Commission on the Future of Agriculture and Agri-food, released its report with similar findings and recommendations. The Commission recommends that "PEI agriculture and agri-food sector should take the lead in developing an assessment of energy opportunities for the sector".

In 2006, the PEI Soil and Crop Improvement Association (PEISCIA) and Agriculture Environmental Services Branch (AESB) of Agriculture and Agri-food Canada explored the possibility of establishing a trial to evaluate the use of short rotation coppice willow as a potential biofuel but also as a phyto-remediation technique in riparian zones to reduce the amount of excess nitrogen fertilizer being leached into surface and sub-surface water.

Willow is a particularly attractive biomass species for several reasons:

1) The BTU value of willow is equivalent to many common hardwoods (maple, beech, etc.);
2) The species of willow used for biomass production can be harvested every 2-3 years for up to seven cycles without having to replant;
3) Biomass willow clones are non-invasive;
4) Very high biomass production potential;
5) Easily established with un-rooted cuttings;
6) Harvestable in a mechanical one-pass cut-and-bale or cut-and-chip
7) Re-sprouts vigorously after each harvest; and
8) Provides many environmental benefits such as run-off control, phyto-remediation and wildlife habitat.

In June 2006 the PEISCIA and AAFC established two demonstration sites. One is located on a potato farm in Meadowbank and the other is located on a potato farm in the Wilmot Valley.

In 2008, PEISCIA and PEI Agriculture, with support from AAFC, established a further 4 research sites on high sloped lands in the central portion of the province. With 28,000 acres of high-sloped agricultural lands in the province, willows might provide further biomass opportunities on marginal farm lands.

Yield data collected in 2009 on the 2006 plots (four years of growth) in Meadowbank and Wilmot Valley, indicates the annual yield averages to be 16.5 Oven Dry Tonnes (ODT) per hectare per year for the SV1 and Viminalis varieties tested.

With the appropriate fertility and moisture, it is clear that biomass willow clones perform very well under PEI growing conditions. Willow production in riparian areas and high slope lands could potentially make a significant contribution to the production of agricultural biofuel feedstock not to mention environmental benefits (phyto-remediation, reduce run-off, wildlife habitat).

2. Executive Summary

A crucial component to a successful willow biomass industry, is the economical harvesting of the material. There is equipment that has been developed to harvest short rotation willow. Some involve baling while other types of equipment involve cutting and chipping at the stump. The harvesting systems must make sense from an economic and environmental perspective given PEI conditions and scale of production.

This report explores some options through a literature review and evaluates a JF Willow Harvester Type 192.

Mr. Bruce McCallum of Ensight Consulting, provided the analytical and knowledge base study of harvesting systems available. Mr. McCallum, who is based in Hunter River, PEI, is a professional forester and farmer who has traveled extensively in Canada and abroad and is current in his knowledge of biomass harvesting systems. Mr. McCallum is a founding member of CanBIO, the Canadian Bioenergy Association.

Mr. Lowell Stevenson, a forestry technician, provided assistance in the in-field evaluation of a JF Willow harvester Type 192.

Both Mr Stevenson and Mr McCallum provided independent reports for their work. This document brings both reports together into one, plus additional information has been provided from the partners and notes from the editor.

The hopes would be to have an individual interested in doing custom harvesting of willow sites by identifying farm scale equipment. PEI is not expected to be large enough to support large scale willow biomass production.

3. Literature review of Willow Harvesters - Ensight Consulting

a. Willow harvesting options

Various harvesting approaches were considered. Perhaps the most suitable system involves a modified corn harvester as it cuts and chips into a trailer in one-pass. An example of this type of machine is a Case New Holland forage harvester which is built in Belgium and costs $400-500,000. A new harvester head has been developed in Pennsylvania specifically for willow harvesting that fits on the Case New Holland forage harvester. Unfortunately, there is only one of these machines operational in North America in New York State. That machine was not available for a trial in Canada. Secondly, the plots on PEI are very small. If the machine had been available, it would have made for a very costly trial. Thus other chipper options were explored.

Figure 1 Case New Holland willow harvester

Figure 2 Case New Holland willow head **Figure 3 CRL Willow cutting head**

A second option explored was the Canadian willow bailer that has a cutting head that will cut and feed the willow directly into a heavy duty bailer. This approach is favoured by Derek Sidders, a scientist working for NRCAN in Edmonton. He has been conducting harvesting trails with this machine recently in different parts of Canada, including Ontario and the west.

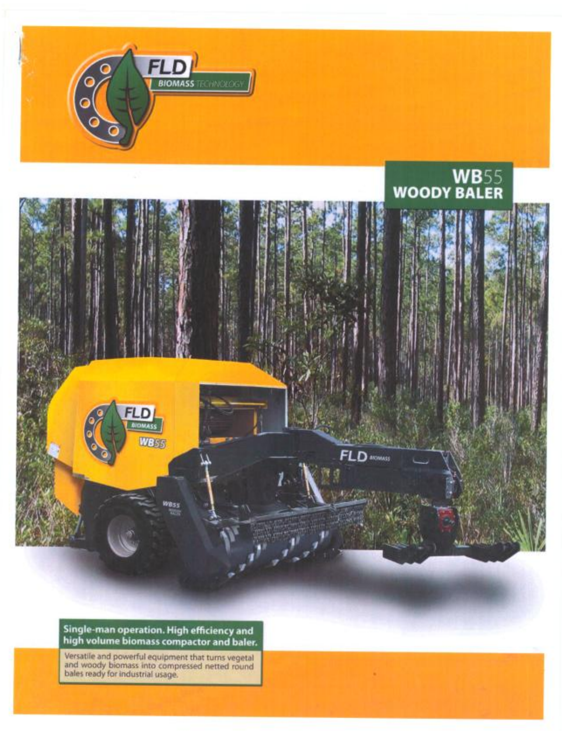


Figure 4 FLD Willow baler

The challenge for us in PEI is “what would we do with these bails after they had been harvested?” The normal approach is to comminute them by grinding them in a tub grinder. The only suitable tub grinders that the consultant is aware of are located in Nova Scotia and operated by Verboom Grinders Ltd. These are large industrial scale machines that are much too large for any foreseeable farm scale willow growing operations.

The second option would be to burn them in a round bale straw burner. There does exist two round bale burners in West Prince on farms. Mr McCallum did express concern that these types of burners have fallen out of favour in Europe because of emission issues.

This led the consultant to consider other harvesting approaches that might a better fit for farm scale operations. Mr McCallum had viewed a somewhat new type of biomass harvesting head in Finland in May of 2009 that seemed to be of interest. These are called “energy heads”. They are single-grip harvest heads that go on the end of forestry cranes that can be mounted on either large farm tractors or forest machine carriers. They are offered by many forest machine manufacturers and have been an area of active machine development in recent years. This is partly because the forest industry has been in a severe recession and the sales of conventional forest machines have dived. The “energy head sector” has been one of the few bright spots because the bioenergy sector has grown with the coincidental rise in energy prices over the last three years.

These energy harvesters are used for thinning or spacing of natural stands to promote future high-value stands, for harvesting along roads and power line right-of-ways and along field edges to push back ingress from the forest.

One machine that is of particular interest is the Naarva-Grip, manufactured by Pentin Paja OY in Joensuu, Finland. This is a short-line manufacturer which sells energy harvesting heads of different sizes and types that can be mounted on many different carriers, including farm tractors. Tractors that have reverse drive capabilities (e.g.,Valtra and NH Versatile) make the best tractor carriers for this application. The controls and hydraulics on the Naarva-Grip are very simple and easily adapted to run off most carriers without elaborate installation work.

Figure 5 Naarva Grip energy head

The willow stands in PEI were described as having stems in the 3”-6” butt diameter range. This is within the harvest range of the Naarva-Grip which can typically handle up to 9”-10” maximum diameter trees for the tractor mounted units. Some of these heads have an accumulating arm capability which allows them to accumulate numerous smaller stems into a more efficient bundle, allowing the operator to harvest small stems with reasonable operating efficiency. Tall trees are usually harvested by reaching up and cutting the tree at perhaps the half way point and then reaching to the bottom of the same tree and gripping and cutting the lower portion of the same tree at the butt. The operator continues to cut and accumulate trees or longer tree sections until full volumetric capacity of the head has been reached. Then the harvested trees are placed in a pile for later extraction to roadside.

The cost of the tractor-mount units with accumulating arms ranges around $8,000 to 9,000.00, not including a crane or carrier. This is a relatively modest cost for a machine that can do a range of tasks in farm forestry in a place such as PEI. This combination of potential tasks is what makes a machine such as a tractor-mounted energy head something of interest in the Atlantic region. After cutting the willow stems, a second operation would be needed to chip the willows.

After contacting the manufacturer of the Naarva-Grip energy head in Finland, Mr McCallum learned that there was already a project in the works to send a Naarva-Grip head to Canada for trials in Newfoundland and possibly Nova Scotia. Dominik Rosser of METLA (the Finnish Forestry Research Institute) and Mark Ryans of FERIC (the Forest Engineering Research Institute of Canada) were involved in this proposed demo project. These are people that Mr McCallum has known for some time through conferences and bioenergy activities.

The Naarva-Grip project had been initiated by Bill Alexander of the Newfoundland and Labrador Forestry Training Association. He was planning to have a Naarva-Grip energy mounted on the carrier of a Newfoundland forestry contractor who would do silviculture operations in the Corner Brook area, producing energy wood for the local pulp mill and improving the quality of the stands.

Bill Alexander had brought his brother (Harold) into the Nova Scotia portion of the project. Harold Alexander is a forestry engineer who operates a small silviculture contracting business in the Digby area using a Finnish Valtra tractor and crane with a conventional harvesting head. Harold has been involved in woodchip production for about ten years, supplying schools and other heating plants in the Annapolis Valley. Mr McCallum also know Harold Alexander and he seeks bioenergy advice from him on occasion.

Ensight Consulting concluded that a Naarva-Grip could be suitable for a willow harvesting demonstration project on PEI and that it made sense to try to tie into the Newfoundland and Nova Scotia demo projects. This was affirmed by not being able to find a suitable tractor-carrier on PEI.

One shortcoming of the PEI willow demo harvest project is that the plots are very small, making it costly to bring a machine in to harvest two plots of about an acre in total. This problem was compounded when it was decided in October that almost half of the Waugh willow stand was to be left for control and growth comparison purposes with the harvested plots. These micro harvest sites made for very expensive harvesting trials.

Ensight Consulting had focused some of their time on trying to arrange a silviculture trial of the Naarva-Grip head in PEI with the co-operation of the PEI Environment, Energy and Forestry Department. The hope was that we could piggy-back a small willow harvest demonstration with the same harvester, thereby reducing the overhead costs considerably and increasing the likelihood that we could get a machine here to do the trial.

Numerous discussions were held with Brian Brown of Environment, Energy and Forestry about arranging a silviculture trial of the Naarva-Grip head on PEI. He offered to provide transport of the machine from Nova Scotia to PEI and back again.

The project seemed to be shaping up nicely in September and October for a tree province demonstration project of the Naarva-Grip harvester including at least one week in PEI. However, the project hit a major bump in the road when the pulp mill in Corner Brook, Newfoundland was shut down indefinitely and that stopped the trial in that province. With the mill shut, there would be no market for woodchips produced from the trial.

However, in late October, the project was brought to the front again. The funding support to bring the Naarva-Grip head to Canada has been carried forward to 2010. METLA and FERIC are still on board and the project appears to be proceeding, albeit somewhat delayed. It now appears that the Naarva-Grip head will be delivered to Canada in late January and a trial will first take place in Nova Scotia in February. Technical questions about mounting the Naarva-Grip on

Harold Alexander's Valtra tractor have been resolved. There is still interest in a demo of the machine in Newfoundland.

The question remains as to whether we can still utilize the Naarva-Grip harvester in a practical willow harvest trial in Prince Edward Island? If we are interested, when could that take place? Ideally, it would occur in the winter months before leaf flush. That would require that we have a thaw followed by freezing to provide access to the stand for machines. No one knows what will happen to the Naarva-Grip after the silviculture trials are finished. At this point, we do not know when that will be.

b. Suitability of the Naarva Grip Head for willow harvesting

The question arises as to the suitability of the Naarva-Grip Head for the harvesting of willow? The Naarva-Grip was recommended for this trial by the consultant for a number of reasons:

1. It is used for harvesting small stems in cleaning or thinning silviculture operations. The literature shows it harvesting stems equivalent to what willow stands.
2. The Naarva-Grip Head is not very expensive at around $8,500.00. It is well within the cost range for farmers or custom operators.
3. The Naarva-Grip Head has simple controls that can be installed easily on a wide range of carriers.
4. The Naarva-Grip Head can be installed on forest cranes designed for farm tractors which are readily available in this region.
5. The Naarva-Grip Head is suitable for energy harvests in thinning or cleaning operations in Canada, which it is used for in Europe. Thus there is good potential that machines of this type can be economically viable because there is enough work to keep them busy.
6. The Naarva-Grip Head can be used to load and unload a trailer to extract the harvested material to a roadside landing where there is good vehicle access or to transport the material back to the farmstead for on-farm use.

Until a trial is conducted, we will not know if the Naarva-Grip Head is suited to use in the Maritimes for willow harvest. It is possible that it is not ideal for the purpose. But one then must ask, what other options exist? In the view of the consultant, there are no ideal solutions available at this time.

Derek Sidders is aware of the Naarva-Grip Head. He has seen pictures on the intra-net. He felt that the productivity would not be adequate. He was also doubtful regarding the durability of the machine. The consultant is not sure about the productivity. That will depend to a considerable extent on the size of the stems and the percentage of horizontal stems that pose problems for all harvesting technologies. (Derek Sidders reports that normal yield for machine harvest is about 70% of available biomass compared to careful manual harvesting.) The consultant is quite confident regarding the durability of the Naarva-Grip Head as it is normally used in trees that are more challenging to handle than willows.

The bailer is another option, but there remain two obstacles. Firstly, the willows will lose moisture more slowly in a bale than if they are piled at roadside under cover. The Finns use roles of impermeable paper to cover chipping piles to reduce moisture content and to keep ice and snow out of the material. Air drying seems to make sense to enhance the energy value of the fibre and to reduce burner emissions.

There has been a trend in woodchip burning technology toward burners that are designed for drier fuels. Dry fuel burners are less costly to build and efficient combustion with low emissions is easier to achieve with consistently dry fuel. The most common approach used in small-scale chipping operations is cut wood one year and to hold it over and chip it the next summer or autumn when the moisture content has been reduced significantly by air-drying.

Secondly, the only suitable grinders are very large and only available in some parts of the Maritimes. There are presently none of these grinders available in Prince Edward Island.

The Case New Holland forage harvester is another option, but it is still under development and it is very expensive at $400-500,000. It is hard to imagine the industry growing to a size that would justify such an investment on Prince Edward Island in the foreseeable future. The small potential harvest blocks on PEI also mitigate against a large and costly harvester.

c. Challenges with willow chip production

There are some fundamental problems with growing and harvesting willow in Maritime provinces that have been observed by the consultant in the course of this project. Willows cannot be harvested until leaf drop to avoid shocking the trees. This essentially means harvesting in November. The weather gets progressively worse as we get into November which makes it tricky to get on the fields to harvest and extract the material. Ground conditions are generally rather poor. There is a narrow window to harvest this material. This could mean that the trees do not get harvested before winter arrives, if the weather is unfavourable. Harvesting could occur during the winter, but that assumes that we get a major thaw to melt the snow, followed by a hard frost to allow machines to operate.

Ideally one would like to use the biomass in the approaching winter. However, according to Derek Sidders, the moisture content of freshly cut willow is about 50%. Fifty percent moisture is quite high and there is little prospect of lowering it through air drying before the main heating season which is December to March.

Only a few industrial plants (e.g., PEI Energy Systems) have burners capable of burning such wet material. That company now prefers to burn dryer (average 35%) material in order to meet its growing heat load. The company offers chip contractors a bonus for lower moisture content in order to enhance the output of their plant.

Small commercial heating plants such as those sold by Vince Court (Bioblast) need fuel below 40% MCWB to run properly. Smaller burners such as the Danish Tarm boilers which are suited to home and small farm use require woodchips of less than 25% moisture as well as consistently small fuel fractions.

Wet material can be mixed with very dry material to produce a suitable fuel in some cases, but that assumes that dry fuels are available for mixing. Wet fuels will likely be discounted to reflect their net energy value.

The woodchips produced in the small trial from the Waugh Farm in Wilmot Valley, PEI, using the Agriculture Canada chipper, were very wet and full of whips - small rubbery sticks. Those sticks would have created problems for virtually all smaller woodchip plants. Those chips are likely what one would normally expect to produce from freshly-cut willows.

Better chippers, equipped with twig breaking attachments and run at 1000 RPM would have helped, but there are not many such chippers in Canada at this time. Some drum chippers are good at screening out oversized materials, but they are not common either, especially in smaller tractor-powered machines.

Aging the material under cover until, say, August would help as the stems would be brittle and twig breakers would be much more effective. However, that would incur inventory costs and there would be some dry matter losses.

The current test plots are micro sites and not suitable for cost-effective production, but they were never intended as production plots. Future willow stands will likely be considerably larger, but they are still likely to be quite small, especially on Prince Edward Island where farms are small. The proportions of farms that farmers will have to take out of row crops (and might plant to willows) are relatively small. This will mean relatively small harvest blocks with frequent moving of machines and the attendant high production costs. If this is the case, it will mean that the most practical use for willow chips produced on Maritime farms will be to meet on-farm energy needs and to forget about trying to compete with woodchips produced from commercial forest operations. Woodchips currently available from commercial contractors on PEI are produced in volume and they are relatively cheap. Chip prices are in the $40-50.00 per green tonne range (delivered) for van loads. Some of these chips come from land clearing sites where conversion to farm land is occurring. In this case, contractors may not pay any stumpage (fee) for the chipping material. Even if some stumpage is paid, forest chips are going to be relatively inexpensive on PEI for the foreseeable future.

d. Conclusion on the Naarva Grip

For all the reasons cited above, it is the opinion of the consultant that the Naarva-Grip harvester head is still one of the more interesting options for harvesting modest-sized willow stands in the Maritime provinces. The consultant did try to coordinate a PEI demonstration of the Naarva-Grip harvester head, but it did not work out. The consultant also concluded that the most practical application of farm-produced willow chips in the Maritimes is likely to be for on-farm needs, particularly on farms that have very little woodland.

4. Other options – what to evaluate?

The partners also searched for options for willow harvest. There were certainly some benefits to the Naarva-Grip harvester in the drying process as the stems could be cut and left for a time to dry. Then it could be chipped for a chip burner or put through a tub grinder. It would also be very capable in cutting the willows. The draw backs would be the ability of the machine to grab all the plant stems in one swing for cutting on some larger plants, and the fact that the willow stems or sticks would need to be picked up and fed through a chipper in a second operation. There is a mechanical possibility for this second operation, but adds to the cost and likely would be cumbersome with the nature of a small multi-stem plant. See Figure 8 photo.

Through internet searches, several different units were identified, but either they were again not at a reasonable cost scale, or rugged enough to take on the task such as the Bender willow harvester in Figure 6. According to a report, the bender did not make usable chips.

However the project partners did come across a modified forage harvester made in Brazil, and adapted in Denmark for willow biomass production.

Figure 6 Bender willow harvester

Figure 7 JF Z200-Hydro/E two row willow harvester

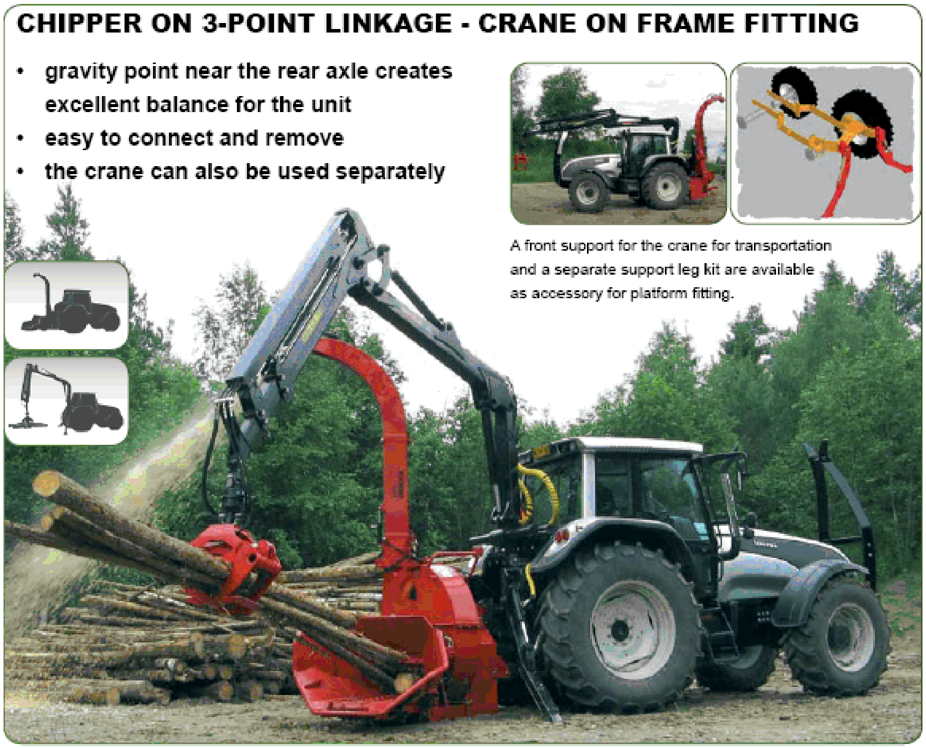


Figure 8 Mechanical fed wood chipper

5. Literature review of the JF192 willow harvester – Ensight Consulting

At the request of the PEI Soil and Crop Association and its partners, Bruce McCallum of Ensight Consulting was asked to investigate a Brazilian willow harvester/chipper that is marketed in Europe by a Danish company, NyvRaa Energipil.

NyvRaa Energipil offer several different willow harvesting machines, but most are designed for large volume commercial harvesting which puts them out of the size and price range of a machine suited to harvesting the small plots that we have and will have on Prince Edward Island for the foreseeable future.

Ensight Consulting contacted Henrik Bach of NyvRaa Energipil of Alborg, Denmark. After a brief discussion, they concluded that the only practical option for the PEI trials is the JF 192 single row tractor-power willow harvester/chipper. This machine is built in Brazil. It was designed originally for harvesting sugarcane. A Danish company from Alborg, NyvRaa Energipil, has modified and adapted the Brazilian forage harvester for harvesting willow in Europe. The company has sold 12-15 units in Europe.

The JF 192 costs 24,000 Euros when equipped with the extended header and hydraulic drive. The extended header allows the machine to harvest (twin) rows which are normally spaced at 75 cm. (The spacing between the twin rows is 1.5 metres.) It also allows the tractor wheels to stay off the willow stems, which is good for maintaining their health and for capturing as many stems as possible without knocking some over.

The hydraulic drive allows the head to be reversed should it plug and it reduces stress and down time. The mechanical drive has a shear pin which will break if the machine plugs. It takes at least five minutes to replace the shear pin, plus the time needed to unplug the head. The hydraulic drive is probably worth the extra cost if you expect that the machine will be utilized for any commercial willow chip production.

The production output with the JF 192 is in the range of 50 m3/hour.

A two row version of this machine is under development. It is expected to sell for about 50,000 Euros. The catch is that it is designed to be mounted on a reverse-drive 240 HP tractor such as a large Valmet. This is a commercial machine package that is out of our league at this time.

NyvRaa Energipil have concluded that 3-5 year old willow stems are too large and too hard on the harvester. They have gone to 1 and 2 year harvest rotations, with substantial use of fertilizer to boost production. The preferred diameter of stems for the JF 192 is 5-6 cm. This raises the question as to the possible need to manually harvest some of the PEI test plots if the stems exceed the 6 cm maximum diameter deemed appropriate for the JF 192 willow harvester/chipper.

NyvRaa Energipil have a few JF 192 units in stock, but expect them to be sold soon. The time to re-order and receive new machines from Brazil is about two months. They must then be modified prior to shipment to Canada. Likely delivery time to Canada is about 3 months from the date of order.

The price for the JF 192 with the extended head and the hydraulic drive is about 24,000 Euros in Denmark. I have requested the cost on the extended header and the hydraulic drive options.

Ensight Consulting concluded that the NyvRaa Energipil is a suitable machine for harvesting trials and early willow chip production in Prince Edward Island with the proviso that steps be taken to limit the stem diameters to 5-6 cm.

6. Evaluation of the 1-row type 192 JF willow harvester

a) Introduction

In August of 2010, AAFC AESB purchased a 1-row 192 JF willow harvester. This harvester was then evaluated on existing willow plots throughout the central part of the province in November of 2011. This trial was conducted (in part) to determine the effectiveness and productivity of a 1-row JF Willow Harvester Type 192. This machine was originally designed as a sugar cane and corn harvester. It was converted and marketed for the purpose of harvesting hybrid willow biomass product. The trial included harvesting plots of planted willow while tracking time and production as well as any equipment issues. The volume of biomass produced was measured at some sites to determine metric tons per hour and the tons per hectare that were produced. Biomass chips were inspected to determine consistency and quality.

Figure 9 JF 192 Willow harvester at AAFC Harrington Farm

Sites sampled included “high slope” as well as riparian areas, outside the mandatory 15 meter buffer zone. A variety of species of willow were planted in various quantities in the trial sites. Most plantings were hybrid willow varieties although planting of native willow was noted in small quantities. The Linwood Rd.(high slope); the Bedeque Bay Environmental Association site in Maple Plains (wet low field drainage area); the demonstration site in Shamrock (high slope); Meadowbank (riparian buffer zone); and Nine Mile Creek (high slope) were included in the harvesting trial.

Prior to harvesting, sites were visited to document site conditions that included drainage, slope, stem diameters, stem heights, planting densities (on some), average row spacing (on some), factors limiting production, GPS areas, etc.

The goal of the plantings was to protect sensitive areas and it was hoped that the biomass produced by “coppicing” the willow would provide a useful biomass “crop” from this land base.

b) Volume estimation

Measurements included the number of stems per plant, the diameter of the individual stems (measured at approximately 30 cm above the ground), the average height of the plants, and row spacing. Measures from representative samples were compiled in a spread sheet. At that point, the information provided some quantifiable description of each of the harvest sites and plant characteristics in relation to the volume of biomass harvested. As willow planting and harvesting advances, it will be necessary to have some calculation of volume (or a "rule of thumb") to allow for the planning of harvesting schedules, the volumes available from a site, and as a tool to track diameters before they advance beyond what the harvester maybe capable of harvesting efficiently. Future volume calculations could be based on the density of plants per hectare, the diameter and number of stems per plant, and plant height. (*A sample tally spread sheet from Linwood Road is attached.)

Following is one possible calculation that could be developed:

*Harvest Volume Estimate = (volume per plant x number of plants per hectare) x harvest area hectares

Tables in the appendix document the details available from production on each site. The average stems diameters were measured following harvesting. (*Stem shatter produced by the harvester made accurate diameter measurements difficult but the averages provided are designed to provide a description of the type of material that was being harvested.) The averages would also provide some clues to the productive qualities of each site and micro-sites within the main sites.

c) Site descriptions:

1) <u>LINWOOD ROAD:</u>
-This site was one of the "high slope" hybrid willow planting sites. It was planted in the spring of 2008.

-The site was situated on a knoll that showed poor growth at the high point

-It was speculated that the poor production in sections was due to a combination of a lack of nutrients and moisture. (*These slopes typically have shale deposits in this locale.)

Figure 10 Lynwood Road August 2011

-The best growth on the willow was noted on an area to the West edge against the Linwood Road. This section was in a natural drainage area and nutrients were being carried into the area by run-off from the adjacent field.

-Plant heights ranged from 4 meters on the richest pocket to 1.5 m on the poorer growing areas. Average height of plants sampled was 2.36 m.

-This site slopes to the West and moderately to the Northwest.

-The site is sheltered by adjacent hedges to the West, North, and East.

2) <u>MAPLE PLAINS:</u>
-This planting was completed in a low poorly drained section of old field.

-Some natural vegetation includes Alder and spike rush as well as heavy grasses. -Vegetation consistent with poorer drainage was noted throughout the site.

-The site became progressively wetter to its Eastern portion as characterized by the lands natural drainage patterns.

-The soils show indication of mottling and would be saturated with water throughout much of the season.

-A heavy cover of grass vegetation and associated rooting provided a mat that limited rutting.

-The product produced was not weighed. The site had low density plantings with wide row spacing at intervals.

-Plant spacing was variable but averaged 1.8 m based on random measurements throughout the site.

-The willows were reasonably consistent with 6 stems (1 at 6 cm, 3 at 5 cm, and 1 at 4 cm).

3) <u>SHAMROCK</u>:
-Shamrock was another “high slope” planting site. It was planted from cuttings in the spring of 2008.

-Run-off from adjacent fields to the Southwest was being controlled by this planting on the Southern end.

-The site was located on an East facing slope.

-Grass was the main vegetation found within the planted area (along with the Willow).

-A stream/ drainage gully was located at the base of the slope in a wooded riparian zone adjacent to the open field where the Willow was planted.

Figure 11 Shamrock site November 2011

-The site appears to have relatively consistent nutrient levels throughout with plant form and height relatively consistent.

-As indicated by Willow growth, nutrient levels would be estimated to be at moderate levels.

-Plant heights range from 2 to 3.5 m (average 2.59 m).

-The largest stems tallied were in the 3 cm diameter range but the main diameters were 1 cm and 2 cm. (The average stem diameter of sampled plants was calculated at 1.54 cm.)

4) <u>MEADOWBANK</u>:
-This site was a combination of a number of planting trials in the riparian zone of the West River watershed, and included a 24-clone variety trial – both native and hybrid.

-Some of the planting reps included dominant Willow development and heights.

-The plantings were located on the base of a slope facing to the South.

-The site was nutrient rich overall with run-off from the field contributing to the nutrients in the planting sites.

-A few rows were located within the 15 m legislated buffer adjacent to the watercourse. No harvesting was completed within this section.

-Heights of 6 meters were noted in some of the dominant sections. Diameters of 6 cm were tallied with a larger number of stems in the larger size range than found on less rich sites.

-During the harvesting of this site, no material produced was weighed and few measurements were made on the plants in the area. However this site is monitored by AAFC Research Branch and data is available on biomass yields on nearly 30 hybrids.

Figure 12 Meadowbank site September 2011

5) NINE MILE CREEK:

-This Willow planting trial was located on a sight characterized as "high slope". It was planted from cuttings in the spring of 2008.

-Plantings were located on a moderate plateau at the Eastern edge of an open field.

Figure 13 Willows at Nine Mile Creek in August of 2011

-The field slopes to the East for 200 meters in sections. There is a distinct possibility of run-off during high water events such as spring run-off or rain storms.

-The base of the slope where the willow was planted appears to contain nutrient rich soils in the drainage zones.

-Heights of 6 meters were noted in one representative plot of "SV1" hybrid willow. The growth was good although the plant form was somewhat "wide" for a one-row harvester.

-Heights in the other three representative plots harvested ranged from approximately 3.5 to 5 m on average. Form was less spread out at the base of the plants and more suited to the one-row harvester.

-A couple of large stems were noted at 5 and 6 cm but the average was 1.81 cm on the plants sampled.

-This site was sheltered by a wooded edge to the Northeast and by the hill to the West, South, and by a moderate knoll to the East.

-This planting of willow is protecting a stream to the North.

d) Harvesting notes

1) LINWOOD ROAD:
- Overall, the stems were relatively small diameter and presented no problem for the harvester.

-Some portions of the planted area had poor growth and low volume of biomass. This would negatively affect production as the harvester was not operating at capacity.

-This was the first site harvested and the operator had no experience with the harvester or the harvesting system.

-Adjustments had to be made to the in-feed distance from the tractor to prevent tires travelling on cut stumps (possibly causing damage to equipment tires).

-The operator experienced difficulty due to poor visibility from the tractor cab. The rear-view mirror was the only option to watch the in-feed during normal operation.

-The rows ended relatively close to the hedgerow leaving little head-land for turning.

-During harvesting of a few of the larger plants, the in-feed clutch mechanism stopped the feeding system. The clump that caused the machine to stop working had 1 stem at 6 cm, 3 stems at 5 cm, and 1 stem at 4 cm. Reversing the feed system and then re-feeding the stems allowed this particular plant to be harvested.

-Some note was made of the angle of the stems in relation to the in-feed system. It was speculated that as the taller plants were cut, they leaned into the next plant ahead of them in the row and this may have caused some difficulty in feeding. It was speculated that a bar could be installed to add to the angle of the plant as it is being cut off but support at the manufacturer suggested this would not be advisable.
-It was noted that cut stumps posed some risk to tires. It is felt that forestry or other heavier ply tires might be needed to prevent tire damage. Planting and harvesting could be completed in a pattern to avoid driving on any stumps so the increased costs related to tires might be avoidable.

-Most stems were uniform and were not wide at the base so minimal misses of stems were attributable to the harvesting system or plant form.

-Production was limited by the short rows on the site and the lack of an adequate headland to turn the machine.

-Cutting of the stems was not clean and caused some stump shatter.

-Some minimal wear was noted on the knife system following the site harvest.

2) <u>MAPLE PLAINS</u>
-No weight was available at this site to track equipment production.

-There was some trouble in harvesting some of the larger clumps on this wet-rich site. Some clutching of the in-feed was noted in plants with 8, 7, & 6 larger stems in one clump.

-This site was quite wet but rutting was minimal due to heavy grass cover.

-It was somewhat difficult to maintain stump heights during harvesting. Heavy grass cover and the soft site caused the equipment to sink and reduced visibility of stump height.

-Harvested stems were relatively consistent in form.

-This site had adequate room at the headlands to turn equipment and this allowed the operator to maintain production and also allowed for less turning or backing-up that might cause excessive rutting on sites with soft soils.

3) <u>SHAMROCK:</u>
-This site was sloped and relatively dry so no issues with equipment rutting existed.

-Plant form was relatively good and the operator was able to maintain constant speed during harvesting. There were very few stems missed.

-Stem shatter and tearing was noted on harvested stumps. Will this create an issue with rot and limit future production of biomass in the coppiced stems?

-Advancing wear and damage was noted on the cutting system of the harvester.

Figure 14 JF 192 and dump wagon harvesting willows in Shamrock

-The operator commented on issues with visibility. The mirror on the tractor was coming in contact with stems during the harvesting operation and would become out of focus. It would be difficult to harvest on a continual basis leaning around to try and watch the in-feed.
-Planting was done leaving an adequate headland to allow for easy turns into the next rows allowing for reasonable transitions between rows. This should allow for adequate production.

4) MEADOWBANK:
-No weight of biomass produced was available to allow for production calculations.

-The willow plantings were located on nutrient rich soils at the base of a slope with substantial erosion in the past. As a result, some extreme growth (and diameters) was noted that created harvesting difficulties.

-Stems were too large (see Tables in Appendix) for this harvesting system and clutching of the feeding system was constant in the larger diameter sections.

-Harvesting production was difficult due to the need to reverse the feeding system to remove jammed stems.

-Willows within the 15 meter buffer zone were not harvested. This patch harvesting did affect the harvesting efficiency.

5) NINE MILE CREEK:
-Consistent stem size and form of the willow plants allowed for good production.

-The harvesting operation had few stem misses.

-The plant spacing, stem diameters, heights, and plant form appear to be relatively close to what would be desirable for all plantings. This would achieve the best production with this machine and also allow for ease of harvesting as well as reasonable yield of biomass per hectare.

-The operator was experienced at this point. Long straight rows would allow for the best production with this harvesting system.

-Side sloping was minimal making alignment of the in-feed on the rows relatively easy.

-Some serious damage was noted on the knives and cutting system. Relatively large chunks of the knives had broken away.

-Stump shatter was noted on the stems.

Table 1: Performance measurement of JF192

LOCATION	AVG. # STEMS/PLANT (*sample)	AVG. DIA/STEM (*sample) (cm)	AVG. PLANT HEIGHT (visual (m))	AREA HARVESTED GPS (ha)	VOLUME HARVESTED (green tonne)	VOLUME PER HECTARE (green tonne per ha)	TIME TO HARVEST (hours)	EQUIPMENT PRODUCTION (green tonne per hour)
Linwood Rd.	5.38	1.48	2.36	0.45	2.95	6.60	0.85	3.47
Maple Plains	4.10	2.65	3.00	0.26	N/A	N/A	N/A	N/A
Shamrock	7.02	1.54	2.59	0.38	2.89	7.61	0.58	4.98
Meadowbank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nine Mile Creek	8.83	1.81	4.62	0.09	2.32	25.78	0.18	12.89

Editor's notes: Table 1 illustrates the performance measurements collected by Lowell Stevenson during the trials. The JF192 work rate ran between 3.47 green tonnes per ha to 4.98 green tonnes per hectare. Linwood Road was the first the operator had used the machine, thus the productivity naturally increased as he got use to the machine. As well the Linwood Road site was one of the lowest biomass yielding sites and Nine Mile Creek was the highest, so naturally the green tonne per hour will also increase.

e) Chip quality and markets

Chips produced by the JF Harvester were randomly sampled and measured to provide some idea of the consistency of the biomass produced. The bulk of the product consisted of pieces around 5 to 6 cm in length. These pieces were lengths of the main stems which ranged from 1 cm and up in diameter. Some of the larger diameter stems at 5 or 6 cm (in diameter) were noted split in half while others remained intact. These "billet" shaped pieces were relatively consistent throughout (*although some pieces up to 10 cm in length were noted). The larger size of chips may add somewhat to the time needed to "dry" the material if that was desired. Smaller chips would create more surface area to allow for drying. Due to the "shrub-like" form of the plant, the plant stems also consist of branch tips. Some of the fine branch tips in the harvested biomass were 10 cm in length but pieces up to 20 cm were noted.

The chipper is a disc system with the stems being fed onto the face of the circular disc. On the face of the disc are four knives installed on an angle to produce the cutting action on the spinning disc. According to some of the staff on hand, there is the potential to add two more knives. This may allow for faster processing but may not cause the chips to be any finer in consistency. It would be important to note that the extra knives would require more power and may require more fuel during the harvesting process.

The consistency of the chips is certainly suitable for the district heating facility in Charlottetown and they have no trouble burning this product. The biomass chips were sampled from one site and found to contain a moisture content of 53.9%. Delivered to the heating facility, biomass with this moisture content would be around $35 per metric ton.

Editors note: A forestry contractor, who supplies the Trigen Energy Plant, received several tandem loads of chipped willow. There was no issue with the chips, other than the higher moisture content, which reduces its dollar value.

Figure 15 Chips produced by JF 192 Willow harvester

The other biomass product typically delivered to the district heating facility consists of wood chips from full tree forestry chipping operations. Moisture content is variable from this source dependent on tree species and the amount of time that the material is left to air dry. Some operations harvest the full-tree and leave them to dry out before chipping. Some chips are also stock-piled and some air-drying lowers the moisture content somewhat. The chips produced by full-tree chipping operations with drum chippers (the forest industry standard) are somewhat smaller in size and consistency. A sample from one local operation showed wood chips around 4 cm square and 1 cm in thickness. The product was relatively consistent with smaller pieces but very few larger pieces were noted.

In this willow harvesting operation, the chips are produced from the initial harvesting process. The only available way to dry the chips would be to pile them in a manner where the piles are not too large and weather is kept off the piles. Some concern was suggested regarding heating of wet material and potential fire hazards. Pile size should be limited to prevent issues. A cylindrical pile less than 2 meters in height was suggested (*although no research was completed on the subject).

In summary, the chip quality is sufficient for the district heating facility that is equipped with a feeding system able to handle the larger sizes and the branch tips produced by the willow chipper. However, many smaller local systems are designed for a consistent size chip and are fed by auger systems. The branch tips and larger sizes would cause “bridging” that would jam the augers and prove unusable for this type of heating. Another system devised to handle these chip sizes efficiently would need to be used or the chips would need to be processed further but this would add additional costs.

Editor’s notes: One tandem load of chipped willow (2,890 kg) did go to a local on-farm chip burner in Lower Bedeque. The moisture content of the willow chips would be approximately 50 to 53 %. The furnace was manufactured by Vince Court, and is about 20 years old. The auger is about 5 feet long and the auger box is 5-inches by 5-inches square cross-section.

Figure 16: Waugh on-farm wood chip burner

The chips sat for about 2-months in a building and then mixed with other dry chips. If straight willow chips were used, the temperature would drop about 25 degrees from the dry chip setting. When the willow chips sat for a couple months to dry, and then mixed with the dry chips, the furnace performed very satisfactorily. The co-operator feels too that they could be dried further in the summer by moving them around.

Figure 17: Waugh on-farm chip burner

Certainly drying is an issue that must be addressed. Henrik Bach from Ny Vraa Bioenergi, who modifies these JF willow harvesters in Denmark, says on his farm he harvests the willows in winter and stores them outside for 3 to 4 months, or until mid summer. Then he moves the chips indoors to a ventilated barn. The moisture content at that time is 20 to 30 %, perfect for a farm boiler.

The co-operator in Lower Bedeque also commented that the willow chips produced with the JF from the Shamrock site did meter through the furnace very well - there were no issues. In fact it was much better than the willows received two years previously when willows were chipped from another site with a hand fed wood chipper. Further investigations are necessary to know for sure if the chip size from the JF 192 is an issue for on-farm furnace infrastructure, but the first trial did appear to be successful.

f) Equipment issues

The JF Willow Harvester Type 192 was powered by a tractor (approximately 155 horsepower). The tractor appeared to provide sufficient power for this single-row harvester.

-The mirror came in contact with the stems and was bent out of focus so the view of the in-feed was poor for the operator. A different mirror system might be needed.

-There was advanced wear (damage) on the cutting knives. These knives need to be manufactured with better material or they need to have a "sturdier design" to prevent issues.

Figure 18 Wear on cutting knives of JF 192

-Clutching of the harvester in-feed stopped the chipper. (The actual chipping portion of the machine function had no difficulties.) The feed needed to be reversed to allow for chipping to continue. This only was notable in the larger clumps with larger diameters. This issue could be prevented by harvesting the sites before the plants become too large.

-The harvested biomass willow was blown into a trailer behind the harvester. A system devised to reduce handling could be used to reduce time and cost and increase production.

-The "valve bank" was located on the back of the harvester. The hoses leading to the bank and the valve bank are relatively exposed. It is suggested that a guard be developed to protect the valve bank in the event that a stem comes in contact with it and causes damage.

-It is suggested that any harvesting on wet sites be completed with more "dumps" of material to keep the loads light to prevent rutting. Timing of harvesting on wet sites might also be used to prevent damage (such as during frozen periods). Maintaining heavy grass cover seemed to provide some flotation on the soft, wet site in Maple Plains.

-It was unclear if this was possible, but changing the angle of the knives on the disc might allow for smaller chip lengths. This might require slower ground speeds or more RPM's on the disc (and more horsepower).

-Visibility was poor from the operator cab of this particular tractor for operation of this harvester.

-Shattering of stems was visible on all the harvesting sites. It is expected that this may cause some issues with plant health. It would be suggested that knife design and maintenance be used to maintain sharp knives and to keep the cuts “cleaner”.

Figure 19 Stem condition after willow harvest

-Some damage may be noted on tires if they travel over cut stumps. Adequate headlands and row spacing (and in-feed positioning) should be used to prevent tire damage. Forestry ply tires could be utilized on equipment but this would add significantly to the cost of the equipment and may not be available in certain sizes.

Editor’s notes: The operator of the harvester from the Research Branch of AAFC suggested that a wider pick-up and skids on the JF 192 would be beneficial. On future plantings of willows, row spacing should be in the 7 to 8 foot range if the JF 192 will be the harvesting system. This would put the last harvested row in the center of the tractor, making alignment easier – less reliance on using a rear-view mirror to guide the feeding system into the willows.

g) Conclusions

-The cutting system will need to be upgraded to a more durable design or different material (grade of steel?) used in the manufacturing process. Wear on the cutting knives (which included a set of “shear knives” and knives on the base of the rotating in-feed drum) was noted early and large “chunks” were missing from the knives by the end of the trials.

-Stump shatter from the harvesting process was extreme. This may cause some weakening of the plants and may somewhat limit the volume productivity in the coppiced stumps. **Editor’s notes:**

A review of the harvested willow sites in 2012, revealed that there was no mortality, and the willow stems had returned as plentiful, if not more plentiful than pre-harvest conditions. The Lynwood Road site had re-grown to an estimated same level of biomass in just one year. The shattering of the stumps has not appeared to negatively affect the willows in year one after harvest. The sites will need further observations in the following years to monitor for disease and insect pressure perhaps related to the shattering.

Figure 20 Re-growth of willows at Shamrock August 2012 after harvest of willows in 2011

Figure 21 Re-growth of willows at Lynwood Road August 2012 after harvest of willows in 2011

-The material produced is relatively "low value". If sold to the district heating facility, it will be more difficult to offset production costs. This material was sold as a low-grade biomass and was valued at the same rate as wood chips produced by "high-production" commercial full-tree chipping forestry operations. With moisture content of 50% and above, the product is currently sold for between $30 and $35 per metric ton.

-The biomass produced is not of sufficient size and consistency of chips to be utilized in local small-scale individual biomass heating systems. If a heating system could be utilized on a farm that would handle this type of material than the product could be used to offset the cost of oil or other heat sources. This may make the material more valuable and could cause the harvester and harvesting system to be more economically feasible.

Editor's Notes: The co-operator in Lower Bedeque commented that the willow chips produced with the JF from the Shamrock site did meter through the furnace very well- there were no issues. In fact it was much better than the willows received two years previously when willows were chipped from another site with a hand fed wood chipper. Further investigations are necessary to know for sure if the chip size from the JF 192 is an issue for on-farm furnace infrastructure, but the first trial did appear to be successful.

-Research should be done to see if any small-scale heating systems are available that would handle this product with few issues. The willow plantations might offset farm heating costs and provide return to the farmer.

-The unit was relatively low-cost (around $35,000.-) and most farms have a tractor that would adequately handle this harvester. A number of farmers could own a machine together or a single owner could provide custom harvesting. This would lower the initial cost of the unit.

-The estimated life-span of this machine is unknown and no data exists. Machine life will be dependent on maintenance and operating procedures.

-To maximize production, headlands should be left to provide adequate turning at the end of each row to be harvested. Harvesting should be completed before diameters become too large. The best production was noted in a planting where stem diameters were consistently 2 and 3 cm in diameter at 30 cm above the ground.

Editor Note: The JF 192 appeared to function well overall and the co-operators are satisfied it is of the scale suitable for our use in Prince Edward Island. The major limitation is that the machine is unable to handle stem sizes of greater than 5 to 6 cms. This limitation was also claimed by the manufacturer. The other investigation required is the cause of the rapid knife wear. This was not expected. Was it an operational factor that needs adjustment, or was it a contribution by the large stem diameters found occasionally on the sites? Further research is required to resolve this issue.

When new establishments of willows are done, year 1 coppicing to encourage increased multi stem re-growth could be done with the JF 192, as opposed to using a 2-cycle brush saw. The only limitation is if the JF might pull out the cuttings from the ground. This could be evaluated in future plantings.

7. JF 192 Willow harvester demonstration day

On December 7, 2011, a Demonstration day for the JF 192 was held at the Shamrock willow site. Phoenix Agricultural Services assisted with the promotions. Personal invitations were made to 13 individuals and organizations, along with the directors of PEI Soil and Crop Improvement Association; staff of the PEI Department of Agriculture and Forestry; representatives of the Model Forest Network; woodlot owners; and forestry contractors.

Advertisements were placed in La Voix Acadienne, the Journal Pioneer, and the Guardian.

On the day of the demonstration, 34 people attended. Many represented a number of businesses and organizations including the PEI Food Technology Centre, PEI Energy Systems, Arsenault Saw Mill, O'Connor Forestry, University College of Cape Breton, Linkletters Welding, AAFC, PEI ADAPT Council, Southeast Environmental Association, PEI Agri Food Alliance, and Deva Forestry. About six to ten producers attended.

The demonstration day was deemed a success. It was a great weather day for early December, and many of the visitors remained on site for well over an hour. The equipment ran smoothly as well.

Figure 22 December 7, 2011 demonstration day in Shamrock

8. High slope willow clone evaluation

In 2008, four areas were selected to evaluate willow biomass production on higher slope agricultural lands. The sites were Shamrock, Lynwood Road, and two in Nine Mile Creek. Each site was approximately 1-acre in size. All four sites were harvested in the fall of 2011 with the JF 192 Willow Harvester. Four varieties of hybrid willows were selected for the replicated trials: SX 67, SX 61, SV1 and Viminalis. As part of the harvester evaluation project, data was collected and reported herein on these high slope variety trials.

In the planting year of these willow sites, there was considerable mortality. It was determined that there were issues with the vitality and quality of the cuttings when planted. In the fall of 2008 and the spring of 2009, there was considerable replanting performed with both rooted plants and cuttings.

With the resulting compromised data of these plots, it was therefore decided that only the weights at the Nine Mile Creek South site would be collected separately from each replication. Of all four sites, it had the lowest overall mortality and replanting at 25%. But for the other three sites, only a consolidated mass weight of all of the replicated plots would be recorded.

At the Nine Mile Creek South site, the four hybrid varieties were replicated four times randomly. Each replication had four rows, and Rows 1 and 3 were collected and weighed. The other two rows were collected and weighed in the overall mass weight. The only exception was Rep D, the first one harvested, as the entire four rows were collected and weighed. However the drive-on

Table 2: Plot design for Nine Mile Creek (South)

Plot rep	Variety
1D	SX 67
3D	SX 61
2D	SV1
4D	Viminalis
1C	SX 67
2C	SV1
4C	Viminalis
3C	SX 61
1B	SX 67
3B	SX 61
4B	Viminalis
2B	SV1
3A	SX 61
4A	Viminalis
2A	SV1
1A	SX 67

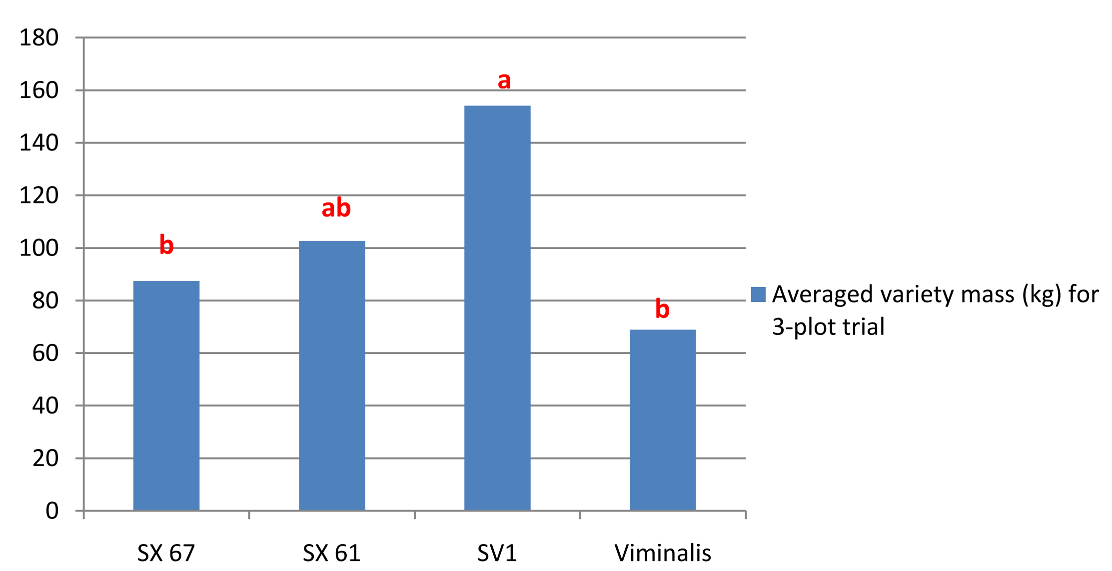
Note
Each plot rep had four rows

weigh scale was not providing an accurate reading to differentiate between each replication, plus there was a high sample loss on the ground. After completing Rep D, the other three replications were then harvested with an improved technique reducing ground loss considerably, and the weights were measured in barrels with a smaller digital scale for more accurate measurements. So Table 3 and Chart 1 only includes Reps A, B and C for analysis of the four willow varities.

Table 3: Mass yield data for Nine Mile Creek South

Variety	Plot Rep	Row 3 (kg)	Row 1 (kg)	Total (kg)	Ave (kg)
SX 67	1A	65.05	36.75	101.8	50.9
SV1	2A	198.03	102.65	300.68	150.34
SX 61	3A	133.45	130.45	263.9	131.95
Viminalis	4A	96.4	54.4	150.8	75.4
SX 67	1B	101.25	63.15	164.4	82.2
SV1	2B	200.05	151.85	351.9	175.95
SX 61	3B	77.35	53.75	131.1	65.55
Viminalis	4B	93.1	49.95	143.05	71.525
SX 67	1C	145.03	113.05	258.08	129.04
SV1	2C	173	99.2	272.2	136.1
SX 61	3C	122.65	97.9	220.55	110.275
Viminalis	4C	67.45	51.95	119.4	59.7

Chart 1: Averaged variety mass (kg) for 3-plot trial



Based on the Nine Mile Creek South site only, SV1's yield was significantly better than both Viminalis and SX67 by 124 % and 76 % respectively. In other words SV1 did consistently better than those two varieties in this one replicated trial.

SV1 also out yielded SX61 by 50%, but because of the variability in the data between the two varieties it may **not** be significantly different and therefore may not be consistent if this trial is repeated.

SX61 out yielded SX67 and viminalis by 17% and 49% respectively, but because of the variability in the data it was **not** significantly different and therefore may not be consistent if this trial is repeated.

The following table illustrates the oven dried tonnes per hectare yield, calculated using 50% moisture content. In this table the mass of the four hybrid varieties for the four high slope sites was consolidated into one weight.

Finally for comparison purposes, the table also shows the biomass yield of other associated trials in Meadowbank and Wilmot Valley of PEI as conducted by Bill Schroeder of AAFC AESB with support from PEISCIA and PEIDAF. The Total Estimated Yield was determined by Mr Schroeder using selected plant measurements.

Table 4: Overall yield results of plots (assume chips were 50% moisture at harvest)

Site	Planting densities (plants per ha)	Total estimated yield (ODT/ha)	Total measured yield (ODT/ha)
High slope sites			
Nine Mile Creek North	4,887	n/a	7.200
Nine Mile Creek South Plot D only	6,078	n/a	12.89
Nine Mile Creek South – entire area planted	6,078	n/a	14.90
Lynwood Road	5,173	n/a	3.576
Shamrock	3,237	n/a	4.203
Source: AAFC AESB			
Wilmot SV1	6,666	64.000	67.200
Wilmot Viminalis	6,666	82.000	64.800
Meadowbank SV1	6,666	75.870	n/a
Meadowbank Viminalis	6,666	34.930	n/a

It should be noted that in Table 4, the AAFC AESB yield data is over a period of 4 growing seasons, and the mortality was practically zero. These plots were planted in the spring of 2006 and harvested in 2009.

Whereas the years of growth for the PEISCIA high slope sites could be either 3 or 4 years because of the mortality replanting. The PEISCIA sites were initially planted in the spring of 2008, with mortality replants being done in the early fall of 2008 and in the spring of 2009. In varying areas the mortality was as high as 100% and as low as 5 % on the replicates, averaging 77 % for all the SV1s and 6.46% for viminalis as examples. All of the plants on the high slope sites were harvested in the fall of 2011.

As a comparison, the 2006 willows at Wilmot and Meadowbank outperformed the 2008 high sloped willows by a very large margin. The purpose of this table is to demonstrate the potential willows have on high slope landscapes if the planting densities were higher, the mortalities due to poor cutting quality were lower, and a fertility program was developed. The landscape at Wilmot and Meadowbank was in the lower portion of agricultural lands, bordering buffer zones. Naturally there would be an abundant of crop nutrients available to the plants. The high slope lands lacked that source of nutrients for the most part and the yield suffered as a result.

From the work done thus far it is clear that short rotation coppice willow performs well under PEI growing conditions and has the potential to displace a significant amount of fossil fuel consumed in PEI.

It is conceivable that many thousands of hectares of short rotation coppice willow could be produced on acceptable marginal agricultural lands and harvested on a 2 to 3 year cycle. The energy produced from burning willows could produce heat or electricity on farms and in hospitals, schools, public buildings and at co-generation plants throughout PEI and the Atlantic region. The City of Summerside has studied a co-generation electricity plant. Cogeneration plants have also been discussed for the O'Leary and Borden areas. At least three PEI farms have round bale burners on their farms. And a large number of farms have wood chip burners as well. Others are talking about pellet production using willows as a possible wood source. And there could be opportunities in neutraceuticals and functional foods.