Final Report

Wisconsin Ditchmass:
A 2010 Road Shoulder Biomass Energy Harvesting Pilot Project

Presented to
Wisconsin Department of Transportation & the
Wisconsin Office of Energy Independence

by
Jamie Derr, Derr Solarmass LLC

APRIL 6, 2011

Abstract

In 2010, Jamie & Robert Derr, Derr Solarmass LLC the farming operation of the Derr Family Farm, conducted a pilot project to test the feasibility of harvesting roadside biomass along Hwy 151 in the townships of Sun Prairie and York. Several states have begun to explore the feasibility of utilizing highway right-of-ways for agricultural use and the Derr's were interested to study its potential in Wisconsin. Several planning meetings took place during the winter of 2010 resulting in a partnership between Derr Solarmass LLC, Wisconsin's Office of Energy Independence and Wisconsin's Department of Transportation. A permit was issued by WisDOT for Derr Solarmass to harvest a 2.2 mile section of right of way along Highway 151 between County Highway V and VV. Harvesting was done on November 4 and 5. Thirty-five large square bales were harvested producing an average yield of 2.03 tons/acre or 5.55 tons per mile. The chemical analysis of the grasses are listed on pages 5 and 6. Results of this pilot showed that harvesting roadside biomass with farm equipment is feasible and yield and quality was sufficient to warrant further study. The knowledge gained in this project can be used for establishing a useful benchmark for road shoulder biomass value. This project was supported by the Wisconsin Department of Transportation and the Wisconsin Office of Energy Independence. Pam Porter of the Biomass Energy Resources Center (BERC) assisted with the study. Additional support was provided by grass ecologists at the University of Wisconsin including Dr. Randy Jackson, Dr Carol Williams and Sue Chamberlain.

Overview

Biomass energy is an important renewable energy resource and potentially a new energy crop for Wisconsin farmers and loggers. A portion of Wisconsin's 114,910 miles of roadsides may be a good source provided that such use of the right-of-way does not interfere with the free and safe flow of traffic. In 2007 a national Freeways to Fuel Program was started by Utah DOT and Utah State University and today many if not most states[1] have begun to explore the potential of utilizing highway rights-of-ways for agricultural or bioenergy production. In 2008, the Federal Highway Administration (FHWA) established the Carbon Sequestration Pilot Program (CSPP) to assess whether modified maintenance of rights of ways can provide a source of revenue to state DOTs (i.e. generate revenue from biological carbon sequestration through sustainable forestry and replacing traditional ground cover with native grasses.

Derr Solarmass LLC approached OEI with the idea of a pilot project to study the right of way adjacent to their farm in Dane County. Little was known about roadside biomass yield or quality and even less was known about the feasibility of harvesting this rough land with standard farm equipment. The Derr's submitted a proposal to OEI in 2009 for the "Ditchmass" pilot. OEI met with WisDOT and both agencies agreed to provide support for this pilot. Wisconsin DOT manages the states right-of-way vegetation for a variety of public purposes including: safety, roadway integrity, erosion control, water quality, habitat, native plant restoration and aesthetics. In addition a range of activities occurs within its rights of ways (i.e. road construction, grading, excavation etc. and utility (gas, water, electric, sewer, cable etc.). On September 8, 2010 a permit was issued by WisDOT for Derr Solarmass to harvest and bale roadside biomass within the Hwy. 151 right of way between County Highway V and VV in Marshall, Wisconsin (Sun Prairie and York Townships in Dane County).

The pilot project was designed to help Wisconsin evaluate, from a farmer's perspective, the production volume, sustainability, economics and feasibility of road shoulder biomass harvesting. The pilot was also designed to help WisDOT explore costs and benefits (i.e. reduced maintenance costs and carbon) to the agency, whether a future expanded pilot program should be done and if so, how and under what constraints.

Methodology

The goal of the pilot was to see if roadside grasses could be successfully harvested and baled with farming equipment and what the chemical analysis of roadside grasses might be.

Several planning meetings with OEI, DOT, BERC and UW took place between February and May. Derr reviewed the Adopt-a-Highway safety video and had two other "on-farm" meetings with DOT to make sure that the harvesting and baling in the right of way was implemented in the safest way possible for both Derr and the traveling public. He met with local equipment dealers to secure the rental of equipment. As a requirement of the pilot project Derr added a rider added to his insurance policy at a cost of $667.00.

Harvesting of the roadside biomass, a comparison of two different cutters took place on November 4 (sickle bar cutter) and November 5 (disk bine cutter). The windrow dried and was baled on November 8 (New Holland large square baler). Bales were loaded onto a truck, driven

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[1] Michigan http://michiganbiomass.com/Update/May2010B.pdf; Texas, http://www.seco.cpa.state.tx.us/re_biomass.htm; Kentucky energy.ky.gov/BTF%20documents/Sluss.ppt; North Carolina http://www.charlotteobserver.com/2010/08/08/1610038/growing-fuel-by-the-roadside.html

to Columbus to be weighed (Columbus Center Travel on Hwy 16) and then transported 16 miles to a neighboring farm to be used as animal bedding. A timelog of the work done on the pilot is found in Appendix 1.

Subsamples were taken from each bale, weighed and dried at the Arlington Farms driers. After they were dried they were ground with a hammer mill. Three separate composite samples were taken from the material, put into three ziplock bags and mailed to Twin Ports Lab in Superior, Wisconsin for chemical analysis. Samples were analyzed for ultimate and proximate analysis (moisture, ash, volatiles, fixed carbon, BTU, C, H, N, S & O) Chlorine and mercury were also tested. Results of the samples can be found in Appendix 2.

Thirty four of the thirty five bales were sold ($5 per bale) to a neighbor who planned to use the bales for bedding. Jamie kept one bale in order to experiment with a mobile pellet mill owned by NightHawk Manufacturing and Repair (Waupon, WI). The results of the pelletizing will be shared with WiDOT and can add knowledge of densification potential for Ditchmass. http://pellets4fuel.intuitwebsites.com/index.html

Results:

Characterizing the Stand

On Sept. 1, 2010, Dr. Randy Jackson, Dr. Carol Williams and graduate student Sue Chamberlain (University of Wisconsin Department of Agronomy) were joined by Pam Porter (Biomass Energy Resources Center) to perform a qualitative survey of the Ditchmass pilot area on State Highway 151 between County Highways V and VV. The crew made visual observations of the plant species present and the relative abundance of each species. Based on these observations four dominant species were identified (in descending rank order): reed canary grass (Phalaris arundinacea; approximately 50% of cover), Kentucky bluegrass (Poa pratensis; approximately 15% cover); smooth brome grass (Bromus inermis; approximately 15% cover), and fescue (Fescua spp, approximately 10% cover). All other species totaled less than 5% cover and consisted primarily of cattail (Typha spp) aster (Diplopappus spp), dogwood (Cornus spp), milkweed (Asclepias spp), and some thistle. The distribution of plants appeared to be relatively homogenous with very few patches or patchiness of the four apparent dominant spp. Underlying the standing vegetation was a deep layer of dead plant matter and a relatively deep duff layer. There was very little roadside debris observed. The standing plant material was dense, and free of disease, fungus, rust, etc.

Yield

A total of 11,700 linear feet was harvested along the pilot site. Approximately 3/4 of this area had two passes (Aprox 1/4 was too narrow or too rough and only had one pass) for a total of 6.04 acres. Thirty five large square bales (24,576 lbs weighed on a truck scale) were harvested yielding 2.03 tons per acre or 5.5 tons per mile.

Yield	
Total feet length harvested	11,700
Harvest width of swath (2 passes @ 15 feet)	30
Total ft2 harvested	351,000
Adjusted ft2 harvested (1/4 of length only had one pass harvested: 75% of width)	263,250
Total acres harvested	6.04
Yield (lbs)	4,066.59
Yield (tons/acre)	**2.03**
Feet/mile	5,280
Total miles harvested	2.22
lbs harvested (35 1/2 bales)	24,576
lbs/mile	11,091
Yield tons/mile	**5.55**

Pilot Project Budget

Below is the estimated versus actual costs of the pilot project. Equipment costs were significantly higher than anticipated.

	Estimated Unit	Estimated Cost	Actual Unit	Actual Cost
Labor	285 hours x $30/hour	$8,550		$8550
Subtotal consulting services				$8550
Rental Equipment: tractor, cutter, baler, rake, ATV Fork-Lift	$3,870	$3,870	Rental Equipment: tractor, cutter, baler, rake, ATV Fork-Lift	$6,607
Fuel, diesel	181 gal x $2.75	$500	70 gal x $2.75	$192
Trucking & Handling	$4 X 50 bales	$200	$4 X 34 bales	$136
Chemical Analysis	10 @ $178/sample	$1780	3 @ $310/sample	$930
Storage	$2/bale	$100	Sold for bedding: received $5/bale x 34 bales	-$170
Subtotal equipment		$15000		$7,695
Total		$15,000		$16,245

Results Biomass Fuel Quality (Chemical Analysis)

All combustion processes — whether the fuel is oil, gas, wood, or coal — emit dozens of exhaust components, all having different characteristics. Emissions vary depending on both the fuel source (i.e. among grasses, switchgrass has shown the lowest levels of particulates and nitrous oxide) and the technology utilized (i.e. combustion, gasification etc.). Most facilities that utilize solid fuels for combustion (i.e. utility or heating plants) receive air permits with specific levels of pollutants that must not be exceeded. Higher concentrations of nitrogen and sulfur can result in increased emissions of oxides of nitrogen and sulfur when combusted. Additionally, higher chlorine concentrations in the fuel can release corrosive gases when burned that can deteriorate the inside of boilers and exhaust ducts and stacks.

Three composite samples were analyzed by Twin Ports Testing Laboratory in Superior, Wisconsin. Twin Ports provides laboratory analysis for a wide range of materials and is the laboratory used by most biomass energy facilities in the Midwest. Proximate, ultimate, chlorine and mercury tests were conducted. Proximate and ultimate analyses are common tests used for determining the properties of solid fuels including biomass materials. Proximate analysis gives the fixed carbon, volatile and ash content of biomass, helping to understand how fuels will combust. The ultimate analysis gives the elemental (C, H, O, S, N) composition of the fuel.

Grass and woody biomass can range from 7-12,000 BTU's. The energy value of the sampled ditchmass grass was 7688 BTU/lb, typical of published BTU values for grasses.

Ideally the ash content of biomass for heating should be below 3%. Anything higher than 8% tends to be a problem. The ash contents of these samples were high (10.74%), dramatically higher than premium or industrial grade wood pellets and higher than grasses typically harvested for fuel. The Pellet Fuel Institute (PFI) has proposed standards of 1.0%, 2.0% and 6.0% for premium grade, standard grade and utility grade pellets. Ash levels might be decreased by blending with other lower ash fuels or setting the cutter bar higher than the 6 inch setting agreed to in this pilot, to reduce the amount of soil and dead plant material.

The mineral content of the fuel is also an important factor in the overall fuel quality. Minerals bound in plant material can cause complications in some biomass heating systems during combustion. Fuel that contains significant amounts of potassium or sodium, sulfur, chlorine, and silica (high-alkali elements) form "clinkers," or fused minerals, that can deteriorate the inside of boilers, melt and bind to the combustion grates and refractory, limiting the combustion efficiency by blocking air flow.

We consulted with Dr. Troy Runge, Director of the Wisconsin Bioenergy Institute who reviewed the analysis. Dr. Runge had been leading the effort to secure biomass fuel for the University of Wisconsin Charter Street plant and had helped to develop the biomass fuel specification for the plant. According to these fuel specifications, the chlorides from "Ditchmass" are nearly three times what the limit would want them to be. The others are close to the specification limit but manageable. The average moisture of the samples was 12% at baling (samples measured by the New Holland baler at the time of baling).

Below is the result of the ditchmass grass samples sent to Twin Ports Testing Laboratory.

Chemical Analysis of Ditchmass Grass Harvested					
	Unit	Sample 1	Sample 2	Sample 3	Avg
Ash	%	10.69	10.83	10.72	10.74
Sulfur	%	0.203	0.201	0.244	0.216
Heating Value	Btu/lb	7666	7697	7703	7688
Carbon	%	43.08	43.30	43.35	43.24
Nitrogen	%	1.55	1.40	1.43	1.46
Chlorine	µg/g	6516	4603	5306	5475
Mercury	µg/g	0.017	0.017	0.017	0.017

Calculating costs of production

Operating Budgets:

For a single farm product like corn, soybeans or hay the costs of production are typically determined by determining the cash costs associated with the enterprise, making accrual (inventory change) adjustments and dividing by the number of units produced/sold. In 2010, the price for large square bales of lower quality hay averaged $72.50 per ton. We prepared two analysis, an operating budget using actual costs from the pilot project and a budget using custom rates.[2] For both we estimated the sale of biomass at $40 per ton for roadside biomass.[3]

Ditchmass Operating Budget (actual costs allocated on a per acre basis)					
	Total	**Unit**	**Quantity**	**Price**	**Amount**
				($)	**($/acre)**
Products					
Roadside Biomass (grassy)		tons dry matter/acre	1.78	40.00	71.20
				Total	71.20
Operating Costs					
Input Expenses (all costs were estimated based on a 6.06 acre pilot test area)					
Fertility					
Phosphorus 18-46-0		lbs of product	0.00		0.00
Potassium 0-0-60		lbs of product	0.00		0.00
Boron		lbs of product	0.00		0.00
Fertilizer spreading		acre	0.00		0.00
Insurance		acre	0.00		0.00
1st year scouting roadside and making maps	12h 0m 0s	hours per acre	1.98	30.00	59.40
2nd year scouting roadside and making maps	2		0.33	30.00	9.90
Insect Control					

[2] http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2007.pdf
[3] http://www.uwex.edu/ces/forage/pubs/hay_market_report.htm

Labor Estimate for cutting, baling, loading	12h 0m 0s	hour	1.98	$30.00	59.40
Energy Expenses					
Diesel Fuel	35 gallons	gal	5.77	2.75	15.87
Gasoline		gal	0.00		0.00
Electricity		KW hr	0.00		0.00
Engine Lubrication		acre	0.00		0.00
Repairs and Maintenance					
Power Units (tractor)	$3/acre	acre	1.00	3.00	3.00
Implements (cutters, balers, telehandlers)	$10/acre	acre	1.00	7.00	7.00
Durables		acre			0.00
Custom Rate Charges[1]		per bale	1.00	9.00	9.00
Total Operating Costs per Acre 1st year					**153.67**
Total Operating Costs per Acre 2nd year					**94.27**
Total Operating Costs per Ton 1st year					**86.33**
Total Operating Costs per Ton 2nd year					**52.96**
NET COSTS 2nd year					**-18.24**

Another way to consider estimate costs might be by using custom rate guides, published every three years by the Wisconsin Agricultural Statistics Services.[4] Custom rates are those rates paid by farmers who hire “custom work.” Custom work occurs when a farmer hires someone outside of the farm operation to do farm work (i.e. tillage, spraying, haying etc.) The average rate for machinery operator is $8-20 per hour. Average rates for rotary mowing is $11.80 per acre, $7.55 per large square bale (greater than 600 lbs). Other rates can be obtained for hourly machinery rental (i.e. tractor, skid steer etc.).

Benefits and Challenges

Benefits

Harvesting road shoulder biomass (ditchmass) coverts unused material into a potential substitute feedstock for energy generation. This locally produced biomass could complement supplies as an blendstock to be mixed with lower ash content materials like wood waste. Biomass can be used in electricity and steam generation and for liquid fuels once second generation plants come on-line. Projects that convert biomass to energy like this one are an efficient and important way of capturing new sources of power that are currently unutilized. The State of WI spends $130 per lane mile currently to mow, this built in savings for collection gives ditchmass a economic competitive edge over other biomass sources even accounting for issues such as ash content. If determined to be economically viable, and after overcoming concerns identified in this pilot biomass could offer a means to generate low carbon energy in Wisconsin.

Harvesting the road shoulder could open new area to farmers that are willing to participate. The window after traditional harvest in late November and early December could be filled by harvesting road shoulders (subject to weather and road shoulder conditions).

Contracting with farmers could be done several ways including:

- Custom harvesting contracts based on dollars per ton harvested with Wisconsin owning the biomass

[4] http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/custom_rates_2007.pdf

- Rental agreement based on area harvested with farmers owning the biomass
- Hybrid version with State and farmer sharing the risk

Conventional forage equipment is capable of cutting shoulder biomass (mostly Reed Canary and Orchard grass) and creates work for this equipment not currently available at this time of the year. Jobs that are seasonal can be extended closer to full time with off-season opportunities like ditchmass harvesting.

Challenges

The most important part of the whole process will be proving the economic viability. Operationally, the most significant challenge may be the initial “scouting” (or surveying) of the road shoulders to identify wet spots, drainage areas, culverts and other obstacles. Being able to identify areas that are too wet to carry the weight of equipment and mapping the boundaries of those areas will be important to determine cutting paths. A hand held ground probe that can sense “carrying capacity” will need to be identified so the person scouting the road shoulder can estimate wet area borders. Most other scouting is visual recognition of the other points of interest. If there are plants or wildlife habitat that should be avoided that can be determined.This scouting may need to be done independently, as the producer’s economic interests may conflict with the protection of environmentally sensitive areas, habit or other interests. This in-depth study should only need to happen when new areas are brought into production, though periodic reviews of producing areas will determine if harvesting intensities are sustainable.

After the cutting paths have been determined identifying any shoulder markers (small plastic ones at the edge of the gravel) or areas that are too narrow for equipment to move without encroaching on gravel shoulder will be addressed. Movement of the equipment will be planned and would benefit from GPS guidance and mapping to minimize operator error. During the pilot, loading of bales necessitated use of the highway shoulder. Traffic control for that shoulder was accomplished using a Dane County highway department truck with shoulder closed flasher and the cost of this would be prohibitive. The actual time on the road shoulder loading the truck was less than two hours. The need for a semi-trailer incorporating a message board and solid side to traffic would be necessary to keep costs down and the public safe. In accordance with WisDOT policies and procedures scouting, harvesting or loading bales will conform to best practices and safety protocols.

Recommendations

Micro-view (this summer’s pilot project)

- Pre-scouting and mapping of road shoulder important
- Identify hand held ground moisture probe that can determine “carrying capacity”
- Cutting paths ideally will be on “high and dry” terrain when possible
- When working in wet areas are day to day weather and moisture must be monitored
- Weather conditions of windrows must be closely monitored for moisture for best quality
- Conducting operations during times for lower traffic volumes is recommended

This pilot study used conventional forage equipment and demonstrated satisfactorily operating on the terrain of highway road shoulders. More research and mapping of potential harvest areas could explore the variety of terrains of road shoulders available for production. A yield of 5 to 10 tons per mile on just one of the three areas of the four lane highway (two sides and middle) is reasonable and could allow for an easy three year rotation. The amount of money WisDOT currently spends for road mowing needs to be compared to harvest expenses. More work to quantify harvesting costs will lead to accurate net-value for ditchmass. Although the grasses harvested had higher levels of ash and minerals than wood, they likely could likely be utilized as blendstock, or co-fired with wood or coal. More research should be conducted.

Macro-view (Expanded statewide program)

- Establish guidelines and standard practices for initial road shoulder “scouting and mapping”, including safety procedures
- Determine harvest intervals (every other year, every three) this determines yield potential
- Estimate potential feedstock volume generated from road shoulders statewide
- Estimate collection and transportation costs related to the estimate of feedstock volume generated statewide
- Encourage testing of roadside ditchmass in state-owned power and heating (steam) facilities
- Fine tune production costs of roadside biomass; model costs for mowing shoulders with increased energy costs in the future
- Conduct outreach to farmers to gauge interest in ditchmass harvesting

Wisconsin may be interested in utilizing a portion of the biomass growing on the road shoulders to power state-owned facilities and help build a new local, biomass industry. This potential conversion of roadside vegetation to energy could lead to a more sustainable future.

Acknowledgements

We wish to thank Leif Hubbard, from the Wisconsin Department of Transportation (WisDOT) and David Jenkins and Maria Redmond, from the Wisconsin Office of Energy Independence (OEI) for their support. We thank Dr. Randy Jackson, Dr. Carol Williams, Dr. Troy Runge for their technical assistance. We also thank Chuck Endres of Mid-State Equipment.

Appendix 1

Time Log

1. Pilot project preparation and planning- 32 hours

   2-22-10 Meeting w/ Pam P - discussed OEI & DOT's needs 2.5hrs x 2 persons

   MOU, permit for access, fence opening, task assignment

   3-2-10 Meeting w/ Pam, Leif, Maria, Pat & Jim @ Hill Farms- project details finalized- 3.5hrs x 5 persons

   Discuss funds distribution, reporting requirements, contact #'s, timeline, carbon effect

   5-14-10 Meeting w Dr Randy Jackson with Pam, Randy & Leif @ Moore Hall- finalize sampling protocol - 1hr (x 3)

   6-7-10 Planning time- research cutters- 4hrs

   6-9-10 Planning time- baler research- 6hrs

   7-12-10 Planning time- cutting paths, timeline planning - 3hrs

   9-8-10 Meeting w/ Leif, Gary & Todd @ Derr farm- sign permit, finalize details visit test area- 3hr

   (don't have date) Review paperwork, looked at test area, meet Todd Matheson

   10-1-10 Meeting w/ UW Researchers, Pam & others @ Derr farm- test site visit- 1 hr

   10-28-10 Meeting w/ Pam & Carol (UW researcher) @ Ground Zero- harvest plan review, prep- 2hrs

   10-30-10 Planning time- cutting path ideas, terrain challeges -3hrs

   11-7-10 Meeting w/ Pam @ Ground Zero- final report discussion- 1hrs

2. Safety training- 8 hours

   9-20-10 buy reflective vests, view Adopt a Highway video, review permits

   Pam bought 4 vests for UW crew and herself (1 hr)

3. Scout terrain of test site- 42 hours

   9-1-10 UW researchers conduct stand characterization (4 x 3 hours)

   9-14-10 Scout test area- 3hrs

   9-16-10 Scout test area- 3hrs

   9-30-10 Measure & mark 1000ft sections- 3hrs (2)

10-8-10 Scout test area- 2 hr

10-28-10 Scout and flag test area- 4hrs

11-1-10 Scout and flag test area- 6hrs

11-2-10 Scout & flag test area, draw maps- 6hrs

4. Equipment rental and prep- 12 hours

   6-18-10 Check local equipment dealer inventory- 3hrs

   8-19-10 Check local equipment dealer inventory- 2hrs

   9-16-10 Check local equipment dealer inventory- 3hrs

   10-27-10 Finalize equipment selection and sign rental paperwork- 4hrs

   11-6-10 Return equipment to dealer

5. Biomass cutting- 44 hours

   11-4-10 cutting w/ N.H. sickle windrower- 10 hrs(2)

   11-5-10 cutting w/ J.D. discbine-10hrs(2)

   11-4-10 drive additional safety truck (2) Pam

   11-5-10 drive additional safety truck (2) Pam

6. Monitor windrow moisture- 6 hours

   11-6-10 check moisture- 3hrs

   11-7-10 check moisture- 3hrs

7. Baling- 20 hrs

   11-8-10 Baling biomass- 8hrs (2)

   11-8-10 UW researchers (4)

8. Loading bales- 16hrs

   11-10-10 load bales from roadside- 8 hrs(2)

9. Bale Sampling- 16 hrs

   11-12-10 core sample each bale 5 times (4 hours)

   11-12-10 core sample each bale 5 times (3 x 4 hours) (UW)

10. Post harvest evaluation-18 hours

    12-7-10 review notes and complete documentation- 4hrs

    Sept-Dec email/phone calls to Twin Ports - 2 hrs (Pam)

Dry, weigh, grind samples -12 hours (UW)

11. Final Report- 56 hours

    Video production, 40 hours (Pam)

    12-16-10 review records - 6hrs

    12-19-10 prepare draft report -4hrs

    12-20-10 prepare final report - 6 hours (Pam)

12. Research- 24 hours

    Research completed with many visits before and during pilot project- 24hrs

Equipment costs

New Holland HW325 sickel-cutter windrower rental- $1500.00

John Deere 4995 Discbine rental-$1500.00

Baler rental- $315.00

Tractor rental- $300.00

Tele-handler rental- $500.00

Tele-handler bale spears attachment- $500.00

Truck rental-$300.00

Kubota rental- $600.00

Sub-Total- $5515.00

Diesel Fuel- 70 gallons @ $2.75 = $192.50

Sample testing- $900.00

Total- $6607.50

Appendix 2

Laboratory Analysis (1 of 3)

Twin Ports Testing Inc.

1301 N 3rd St • Superior WI 54880 • 715-392-7114 • 800-373-2562 • F 715-392-7163 • www.twinportstesting.com

Wisconsin Office of Energy Independence
609 Riverside Dr
Madison WI 53704

Date Received: Jan 5, 2011

Date Tested: Jan 10, 2011

Attn: Pam Porter

Sample Log No: 11C0045
Sample Designation: Grass Sample 1

	METHOD	UNITS	MOISTURE & ASH FREE	MOISTURE FREE	AS RECEIVED
Moisture Total	ASTM D3173	wt. %			2.63
Ash	ASTM D3174	wt. %		10.69	10.41
Volatile Matter	ASTM D3175	wt. %		71.59	69.71
Fixed Carbon By Difference	ASTM D3175	wt. %		17.72	17.25
Sulfur	ASTM D4239	wt. %		0.203	0.198
Gross Heating Value	ASTM D5865	BTU/lb	8584	7666	7465
Carbon	ASTM D5373	wt. %		43.08	41.95
Hydrogen	ASTM D5373	wt. %		6.21	6.05
Nitrogen	ASTM D5373	wt. %		1.55	1.51
Oxygen	ASTM D3176	wt. %		38.26	37.25
Chlorine	ASTM D6721	ug/g		6516	6345
Fluorine	ASTM D3761	ug/g			
Mercury	ASTM D6722	ug/g		0.017	0.016
Sodium Oxide In Ash	ASTM D3682	wt. %			
Hardgrove Grindability Index	ASTM D409	wt. /Index			

Additional:

Twin Ports Testing Inc.

1301 N 3rd St • Superior WI 54880 • 715-392-7114 • 800-373-2562 • F 715 392 7163 • www.twinportstesting.com

Wisconsin Office of Energy Independence
609 Riverside Dr
Madison WI 53704

Date Received: Jan 5, 2011

Date Tested: Jan 10, 2011

PO Number:

Attn: Pam Porter

Sample Log No: 11C0046
Sample Designation: Grass Sample 2

	METHOD	UNITS	MOISTURE & ASH FREE	MOISTURE FREE	AS RECEIVED
Moisture Total	ASTM D3173	wt. %			2.45
Ash	ASTM D3174	wt. %		10.83	10.57
Volatile Matter	ASTM D3175	wt. %		71.16	69.42
Fixed Carbon By Difference	ASTM D3175	wt. %		18.00	17.56
Sulfur	ASTM D4239	wt. %		0.201	0.196
Gross Heating Value	ASTM D5865	BTU/lb	8632	7697	7509
Carbon	ASTM D5373	wt. %		43.30	42.24
Hydrogen	ASTM D5373	wt. %		6.13	5.98
Nitrogen	ASTM D5373	wt. %		1.40	1.37
Oxygen	ASTM D3176	wt. %		38.14	37.20
Chlorine	ASTM D6721	ug/g		4603	4491
Fluorine	ASTM D3761	ug/g			
Mercury	ASTM D6722	ug/g		0.017	0.017
Sodium Oxide in Ash	ASTM D3682	wt. %			
Hardgrove Grindability Index	ASTM D409	wt. /index			

Additional:

Twin Ports Testing Inc.
1301 N 3rd St • Superior WI 54880 • 715-392-7114 • 800-373-2562 • F 715-392-7163 • www.twinportstesting.com

Wisconsin Office of Energy Independence
609 Riverside Dr
Madison WI 53704

Date Received: Jan 5, 2011

Date Tested: Jan 10, 2011

Attn: Pam Porter

Sample Log No: 11C0047
Sample Designation: Grass Sample 3

	METHOD	UNITS	MOISTURE & ASH FREE	MOISTURE FREE	AS RECEIVED
Moisture Total	ASTM D3173	wt. %			2.53
Ash	ASTM D3174	wt. %		10.72	10.45
Volatile Matter	ASTM D3175	wt. %		69.26	67.51
Fixed Carbon By Difference	ASTM D3175	wt. %		20.02	19.51
Sulfur	ASTM D4239	wt. %		0.244	0.238
Gross Heating Value	ASTM D5865	BTU/lb	8627	7703	7508
Carbon	ASTM D5373	wt. %		43.35	42.25
Hydrogen	ASTM D5373	wt. %		6.10	5.95
Nitrogen	ASTM D5373	wt. %		1.43	1.39
Oxygen	ASTM D3176	wt. %		38.16	37.20
Chlorine	ASTM D6721	ug/g		5306	5172
Fluorine	ASTM D3761	ug/g			
Mercury	ASTM D6722	ug/g		0.017	0.017
Sodium Oxide in Ash	ASTM D3682	wt. %			
Hardgrove Grindability Index	ASTM D409	wt. /index			

Additional: