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Project Title: Lowering the Cost of Bio-energy Feedstocks while Providing Environmental Services – A Win-Win Opportunity

Contract Number: RD3-1 **Milestone Number: 3** **Report Date: April 5, 2011**

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Congressional District: **Minnesota fifth (U of M Sponsored Projects Administration)**
Minnesota fourth (U of M CINRAM)

MILESTONE REPORT

"Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund."

Executive Summary (Period between 10/22/2009 and 4/23/2010)

The project continues to develop pretty much as planned. We still need to obtain ash for the research on ash application but that is being worked out. We now have initial data from the agronomic trials that were measured during the last growing season and are gearing up for new plantings and monitoring older plantings in the coming growing season. Drought affected our study of weeds in the cropping systems, but we were able to explore the impact on biomass when left in the field over winter and preliminary results suggest a minimal impact on dry matter pointing to greater flexibility in harvest periods. Working with existing data we continue to explore models to adequately predict the impact of perennial crops on water quality and quantity (storage). We are exploring the Stanford University Natural Capital Project's INVEST model that would allow us to include perennial cropping impacts on a variety of ecological services in our modeling efforts. Faculty at the UMN have been key players in the development of that model and a former graduate student who worked on our CINRAM projects is heading up their hydrology modeling efforts. We are working closely with him as we develop our models. Our partners continue to explore the ecological services markets as we move forward and have completed some preliminary work on those markets although the markets are dynamic and we continue to follow their development. Our LCA team continues to develop their framework for analysis working with our researchers to define and access the data necessary for their analysis. Being a 5 year project we will continue to gather and refine data and modeling incorporating that into the final analysis. We have also been able to leverage the Xcel funding to obtain an additional $626,600 of EPA funding to use the information from this project and other efforts to develop decision support tools for agencies and land managers.

The project goal is to develop an efficient system for the production, pre-processing and delivery of biomass feedstocks for energy production that minimizes feedstock cost for energy facilities while maximizing landowner income and the environmental benefits of biomass production.

The project objectives are:

- Establish, research cultural practices, and estimate costs and potential cost savings for the establishment, management, pre-processing and transport of perennial biomass feedstocks from field to energy facility.
- Estimate potential energy, wildlife, water quality, carbon and soil health benefits from targeted perennial biomass feedstock plantings.
- Value environmental benefits for potential payments to landowners who provide environmental commodities.
- Complete an integrated assessment of multiple ecological services markets currently being used; identify potential buyers of ecological services provided by perennial biomass energy crops; develop an integrated ecological services payment package.
- Develop a model for the production, pre-processing and delivery of perennial biomass feedstocks to energy facilities including a life-cycle assessment of the system from field to facility.

Technical Progress:

I. Biomass crop production field to farm gate (Note: Plot diagrams are included in Appendix A.)

Experiment 1: Establishment strategies for weed control

Objectives: weeds often provide excess competition with native grasses and prevent their establishment. Our goal is to develop new approaches for weed control in establishing native perennial grasses and grass-forb polycultures. Establishment treatments will include winter rye, spring oat, and barley companion crops, herbicides, and mowing for weed control.

No additional data was collected from plots established in spring of 2009 because drought reduced establishment and yield of native plants. We will continue to follow the development of the plantings and include them in data collection and harvest operations in 2010. In some cases, seeds that did not germinate due to the drought may become established and in others initial poor stocking levels may improve with additional rainfall.

Planned Activities for 2010

These plots will be harvested in November of 2010. We are planning the establishment of the experiment at three locations in May of 2010. The locations will be at Belle Plaine, and Rosemount, Minnesota.

Experiment 2: Optimum planting dates for native perennial crops

Objectives: There is debate regarding the best time to establish native perennial prairie plants. Some feel that winter and late spring overseeding is an effective and low cost approach. We determined the effect of planting date on the establishment of native perennial plants.

Experimental design: Randomized complete block with three replications. See Appendix 1 for a diagram of the plantings.

Treatments: Whole plot treatments are native plant species: 1) Switchgrass grown alone, 2) a native grass tertiary mixture of switchgrass, big bluestem, and indiangrass, and 3) a mixture of switchgrass, big bluestem and indiangrass with four native forbs and four native legumes.

Subplot treatments within the whole plots were three dates of seeding: Early December before snowfall; January-March; and June. This is a similar layout to Experiment 1 in which large plots are established with the grass and and grass and forb mixtures are planted on a large plot. Within that plot the planting dates were varied to understand the impact of the planting date on crop characteristics.

Accomplishment: We broadcast seeded a mixture of switchgrass, big bluestem and indiangrass with four native forbs and four native legumes on three dates: early December before snowfall; March; and June. To provide variable amounts of cover we also compared seeding into a tilled seedbed with seeding into a fall seeded oat companion crop. The seeding rate of the native plants was 50 seeds per square foot. The plots were seeded on a silt loam soil at Rosemount.

Plant counts in July, 2009 indicated populations of native grasses (switchgrass and big bluestem) of 7.3, 1.7, and 7.0 plants/foot^2 for seeding on bare ground in December, 2008, March, 2009, and June, 2009 and populations of 13, 1.7, 0.3 plants/foot^2 for seeding into an oat residue in December, 2008, March, 2009 and June, 2009**.** Native forbs and legumes did not establish on any date when seeded into bare ground or oat residue.

Interpretation

Native grass populations of greater than 5 plants/foot^2 in the year of seeding are considered to be excellent; indicating that native grasses could be best established by December seedings. With this planting time, seeds will be incorporated into the soil by precipitation and freezing and thawing of the soil. The March, 2009 seeding was unsuccessful likely because a cycle of warm and freezing air temperatures in April, 2009 promoted germination followed by freezing of the seedlings. The reason for the failure of forbs such as legumes and sunflowers to establish on any date is unknown; however, in case the presence of dormant seeds prevented establishment, we will continue to monitor for future establishment. We had hypothesized that use of killed oat residue on the soil surface would have protected the seed and enhanced establishment. This was beneficial for the December, 2008 seeding but not for the March, 2009 or June, 2009 seedings, likely because the residue had decomposed and was not present.

Planned Activities for 2010

The results of winter seeding trials can be greatly influenced by winter and spring growing conditions; therefore, this trial will be repeated in 2010-2011 at 2 locations

<u>Experiment 3</u>: Optimum harvest dates

Native plants are typically harvested for biofuel after a killing frost in November, requiring long-term storage of the harvested biomass. With outside storage, plant biomass degrades and suffers from a loss of dry matter. Instead of storage, an option is to have multiple harvests of forage from the field.

Objectives: Determine the effect of harvest date on the yield, energy content, ash content, and persistence of native perennial grasses and grass-forb polycultures

Experimental design: Randomized complete block with 4 replications. We sampled plantings of switchgrass and native plant polycultures on four dates of harvest: September, 2009, December, 2009, and March, 2010.

Accomplishment: Biomass and dry matter content from within the fuel shed (Rosemount, Belle Plaine) as well as from a site in southern Minnesota (Lamberton) and central Minnesota (Chisago) are shown in Table 1. Initial biomass yields ranged from 1.4-2.5 ton/acre. Yields from all locations decreased over time but at some locations not significantly.

Interpretation: These results indicate that biomass can be left in the field from September to May without a significant loss of dry matter. Dry matter content varied over harvest date and location, and was likely affected mostly by the weather conditions. Dryer forage is preferred in a biofuel source because of reduced transportation and harvest costs. These plant materials will next be subject to analysis for mineral and ash content.

Table 1. The effect of harvest date on native plant biomass yield (ton/acre) and dry matter percentage (a reflection of moisture content) of native plant biomass harvested at 4 sites within the fuel shed.

Rosemount

	Cut 1 9/29/2009		Cut 2 12/2/2009		Cut 3 3/31/2010	
	DM	tons/acre	DM	tons/acre	DM	tons/acre
Ave	97	2.47	82	2.22	82	2.30

Belle Plaine

	Cut 1 9/29/2009		Cut 2 12/2/2009		Cut 3 4/2/2010	
	DM	tons/acre	DM	tons/acre	DM	tons/acre
Ave	54	1.57	64	1.26	84	1.21

Chisago

	Cut 1 9/29/2009		Cut 2 12/2/2009		Cut 3 4/5/2010	
	DM	tons/acre	DM	tons/acre	DM	tons/acre
Ave	59	1.53	70	1.39	91	1.39

Lamberton

	Cut 1 9/2/2009		Cut 2 11/10/2009		Cut 3 3/5/09	
	DM	tons/acre	DM	tons/acre	DM	tons/acre
	24	2.05	91	1.84	88	1.56

Experiment 4: Fertilizer replacement value of biofuel ash

The combustion of herbaceous biofuels will generate a significant amount of ash that is often considered a waste product but that potentially could have value as a fertilizer. Recycling of this ash to the soil will be an environmentally sound practice that also provides a productive use of the ash generated by combustion.

Objective: The overall objective is to answer fundamental questions related to the agronomic use and potential environmental impacts of ash generated from combustion of herbaceous native perennial biomass at the Rahr Malting facilities.

Accomplishment/update:

All research on ash evaluation is delayed because since the Koda Power facility just went on-line they are currently not burning native grasses. Ash application will not occur till the ash is generated and characterized. Projected date of first application is in spring 2011.

II. Moving biomass from road/farm gate to facility

This activity will be undertaken by Koda Energy. Some of the work was initiated prior to the project start date as part of their commercial operations but they continue to evaluate other options for supplying biomass to their facility. Information from Koda Energy will be incorporated into the Life Cycle Assessment and progress on this area will be reported in future milestone reports.

KODA will be evaluating different options to be able to guarantee a constant flow of biomass to their facility. They will be evaluating: 1) different feedstocks based on availability and price; 2) the potential for locating and developing a staging area where biomass feedstocks can be pre-processed prior to being transported to the facility; and 3) the logistics of moving feedstocks from the field/harvest site to their facility.

As the project continues we will be incorporating the Koda Energy information into our overall analysis and that information will be reported on as it is incorporated into the Life Cycle Assessment and as part of our supply chain analysis. Koda is exploring different options for handling the needed supply for their biomass facility. They will be using a percentage of grasses and prairie mixes but are now considering a greater use of woody biomass. Our project, through other funding sources is also exploring dedicated woody crops as well as brushland harvest as part of prairie maintenance operations by the DNR and other organizations. We will be able to include that information in our analysis to the extent that information becomes available from our other research and other sources before the end of the project.

Another important issue that is being explored by Koda is the staging of the biomass supply. Because of limited available storage on site at the facility, Koda is considering establishing a site for gathering and preprocessing biomass that would then be moved to the facility. This is another area we will be able to report on as the project progresses.

III. Measure and value environmental benefits

In this area we will measure and evaluate the specific impacts of biomass crops on the environment including: 1) changes in gamebird populations on areas planted and managed for biomass feedstocks; 2) changes in water quality parameters (turbidity, sediment, nitrogen and phosphorus concentrations); 3) register values reflected in emerging ecosystem markets for water quality and carbon and others as they emerge such as biodiversity; and 4) preparation of a life cycle assessment which allows us to estimate environmental impacts associated with the production, harvest and combustion of biomass crops including an evaluation of resource use and emissions as the crops are produced, transported and combusted.

A. Wildlife impacts

Our wildlife expert continues to monitor the impact of biocrops on grassland songbird populations. The project funded work related to wildlife (grassland songbird) will be initiated in Fall of 2011. By building upon previous work done by our wildlife specialist, we are able to dedicate project funding to complement that work and have a much better understanding of the wildlife issues. During this project reporting period, our project was in the winter season and, due to winter migrations, there are no songbirds to monitor.

B. Water quality assessment – Begin monitoring watershed

Overview of 2009-2010 Accomplishments

Data collected up to the end of the field season of 2009 were formatted for use in a modeling workshop in January, 2010, in which the InVEST modeling platform was introduced by Dr. Driss Ennaanay of the Natural Capital Project, Stanford University. Dr. Ennaanay provided guidance in using our data for larger scale systems and provided training of our graduate students in modeling applications using InVEST. Applying WETHAWQ was found to require water quality data that were in excess of data collected at our sites; therefore, we are considering the SWAT model and others that are less data intensive but that are capable of examining different scenarios of perennial cropping systems and wetland complexes on agricultural watersheds in southern Minnesota. Model calibration and testing is planned for 2010-2011 using all available data from the monitoring sites.

Planned Activities for 2010

Monitoring will continue on all project sites parallel to analysis of data from the field sites.

C. Integrated assessment of ecological service markets

The Ecological Services Team continues to meet as needed. Following is an update of activities as of April 2010:

- IATP has continued with their market assessment which is ongoing. Due to the dynamic nature of the market for ecological services, this activity will continue with regular updating as that market develops.
- Rural Advantage, working with IATP and the University of Minnesota has completed the survey of non-market values and a summary of the results is included as Appendix B. to this report. A Master's paper was prepared by a graduate student in the Humphrey Institute of Public Affairs. A questionnaire was completed by 725 Carver, Dakota, and

Scott county residents, which gave a response rate of 29 percent, to determine how much they would be willing-to-pay (WTP) to utilize the recreational services at a converted site. Using the contingent valuation and hypothetical trip cost models, some support exists for the perennial grass conversion. However, 52 percent would not be willing-to-pay for the conversion, and 64 percent would not visit the converted land. . The initial assessment of markets for ecological services was included in Milestone Report 2.

- We are initiating preparation of a landowner survey to identify constraints to adoption of perennial crops (grasses and woody species) for the production of biomass that will be administered toward the end of the year.
- Rural Advantage is a partner on a Conservation Innovation Grant that is identifying and developing markets for ecological services in the Minnesota River Basin. Drs. Bill Easter and Dean Current from our team are on the National Advisory Board for that project.

Planned Activities for 2010

We will continue our work with Rural Advantage and IATP to identify potential markets for ecological services and develop and administer the landowner survey.

D. Life cycle assessment

Overview of 2009-2010 Accomplishments

We investigated quantity of farm inputs and energy use from previous studies to determine direct emissions from inputs, products, and energy use for switchgrass cultivation and harvest. Additional emissions data for capital goods manufacturing required for biomass electricity systems such as tractor, truck and other infrastructure was also collected.

In order to better assess environmental benefits of biomass electricity, our initial boundary for environmental LCA study was revised to include processes (see appendix1);

The Koda Energy Project provides thermal energy for Rahr Malting Company and excess electricity for Xcel Energy.

Planned Activities for 2010

The revised system boundary is to determine environmental credits of co-products and by-products produced in the Koda Energy and the Rahr Malting Company. The co-products in Koda Energy are excess heat and electricity sold to the Rahr Malting and Xcel Energy. Ash waste generated from the combustion of perennial biomass at the Rahr Malting is sent back to farm and used for fertilizer replacement. The new system boundary will be used to refine electricity generation scenarios for comparative Life Cycle Inventory analysis with coal-fired electricity as baseline.

In order to complete LCI development, appropriate process inputs data is being gathered by close coordination with the other research groups.

- Farm inputs, nutrient cycle, direct emissions (fertilizer and pesticide run-offs to local watershed) from experiments data and water quality assessment
- Distance and fuel use in transportation by energy feedstocks supply

- Process inputs to and direct emissions from electricity generation (in coordination with KODA energy)

Due to seasonal variation of feedstock availability, Koda Energy currently uses sawdust, barley sprouts, and oat hulls for electricity generation. Thus, farm inputs and emissions data need to be developed separately by energy crops. Further analysis for determining transportation distance by local feedstock availability will be done by Koda Energy based on local availability of energy crops close to power plants. Process input and direct emissions data for biomass power plant

IV. Economic assessment of biomass production and delivery system

This research area looks at the financial and economic aspects of biomass production from the perspective of the landowner/farmer who may be interested in producing biomass feedstocks for the market and also the value of the environmental services (water quality, recreation, carbon) to society both qualitatively and quantitatively.

A. Cost Benefit Analysis – Plan activities and begin data collection

Planned Activities for 2010

We will continue to gather data on:

- Costs of establishment
- Costs of maintenance of plantings (fertilization, weed control, etc.)
- Cost of harvest
- Transport costs (this will be done in coordination with KODA energy)

This information will be integrated with the data being developed through the planting and cultivation experiments.

B. Valuation of ecological services

Overview of 2009-2010 Accomplishments

This will be done in coordination with **IIIC** above. Results from **IIIC** will be used to help determine how the public values ecological services which will allow us to use those values for our analysis. In addition to the information gathered through the survey, we will be gathering data on the emerging markets for carbon and water quality credits. As previously reported Linda Meschke continues to be involved in a USDA Conservation Innovation Grant project which is studying payments for environmental services in the Minnesota River Basin and Dr. Bill Easter and Dr. Dean Current on our team continue to serve on the National Advisory Committee for that project continue to provide another source of information for this work.

Planned Activities for 2010

We will continue gathering data on existing options for payments for environmental services as well as new initiatives. This information will be combined with the data generated through the survey instrument.

Project Status: The project continues to meet the timeline with some minor delays but with good progress in most areas. The ash fertilization task continues to be delayed due to the lack of ash from grasses from the KODA energy facility. We are working with KODA and other partners to resolve this issue and expect to complete this task before the end of the project.

LEGAL NOTICE

V. Appendices

A. Plot diagrams for Objective 1 – Biomass Crop Production

B. Summary Results from the Survey to Estimate Values of Environmental Services

C. Revised Process Flow Diagram for Life Cycle Assessment

D. Bio-baler Demonstration Report

A. Plot diagrams for Objective 1 – Biomass Crop Production

NES10 ROS10 PP & RAND.

Randomization

Treatment	Cover Crop Crop	Cover Crop Harvest Time	Entry #	Native Crop	Native Entry #	Rep 1	Rep 2	Rep 3
A	Barley	Forage	5	Switchgrass	1	109	212	313
B	Barley	Forage	5	3 grass mix	2	102	209	316
C	Barley	Forage	5	CP-25	3	101	217	314
G	Oat	Forage	6	Switchgrass	1	117	206	317
H	Oat	Forage	6	3 grass mix	2	111	201	307
I	Oat	Forage	6	CP-25	3	108	207	302
M	Canada Wild Rye	Forage	4	Switchgrass	1	114	204	308
N	Canada Wild Rye	Forage	4	3 grass mix	2	103	214	311
O	Canada Wild Rye	Forage	4	CP-25	3	105	218	305
P	none	Forage	blank	Switchgrass	1	115	203	310
Q	none	Forage	blank	3 grass mix	2	107	215	304
R	none	Forage	blank	CP-25	3	113	211	301
D	Barley	Grain	5	Switchgrass	1	106	210	309
E	Barley	Grain	5	3 grass mix	2	112	213	315
F	Barley	Grain	5	CP-25	3	104	208	303
J	Oat	Grain	6	Switchgrass	1	110	205	312
K	Oat	Grain	6	3 grass mix	2	116	202	318
L	Oat	Grain	6	CP-25	3	118	216	306
S	none	Spray		Switchgrass	1	122	221	322
T	none	Spray		3 grass mix	2	121	220	321
U	none	Spray		CP-25	3	120	222	320
S	none	Spray		Switchgrass	1	420		
T	none	Spray		3 grass mix	2	421		
U	none	Spray		CP-25	3	422		
V	fill	fill		Switchgrass	1	119	219	319
V	fill	fill		Switchgrass	1	419	519	619

NES10 ROS10 PP & RAND.

Native Establishment Strategies, 2010 UMORE Park, Rosemount, MN

Planting date: 5/28/2010 **(NES)** - EXCEL energy grant

Field: d-5

N

101	107	113	ALLEY	301	307	313	72 ft
102	108	114		302	308	314	
103	109	115		303	309	315	
104	110	116		304	310	316	
105	111	117		305	311	317	
106	112	118		306	312	318	
201	204	207		210	213	216	
202	205	208		211	214	217	
203	206	209		212	215	218	
119	219	319		419	519	619	
120	121	122		320	321	322	
220	221	222		420	421	422	

FLAX10

B. Summary Results from the Survey to Estimate Values of Environmental Services

A draft questionnaire was designed to address the research objectives developed under the Madelia Project. In consultation with the ECoPayPack team, question revisions were made until the everyone agreed on the survey's final content. Questionnaire pretesting took place over two weeks from July 6 to 17, 2009 by postal mail. After revising the survey to accommodate the recommended changes suggested by respondents taking the preliminary questionnaire, the final version was mailed on July 31, 2009. The returned questionnaires were collected during the period of July 31 through October 1, 2009.

A total of 2,500 surveys were mailed to respondents in Carver, Dakota, and Scott counties. By October 1, 2009, 725 respondents completed and mailed back the survey. The data analysis consisted of analyzing relationships between the respondents' willingness-to-pay (WTP) for improvements in recreational services as a result of the conversion to perennial grasses.

A summary of the average values and ranges for the WTP, number of visits, length of stay, demographic variables, recreational services, and environmental services are shown in Tables 1-4.

Table 1: Average Values and Ranges of Pre and Post-Perennial Grass Conversion for WTP, Number of Visits, and Length of Stay

	WTP Before	WTP After	Number of Visits Before	Number of Visits After	Length of Stay Before	Length of Stay After
Average Value	$0.85	$2.43	0.133 visits	0.694 visits	0.106 days	0.360 days
Range	$0-more than $15	$0-more than $15	0-more than 5 visits	0-more than 5 visits	0-more than 2 days	0-more than 2 days

Table 2: Average Values and Ranges of Demographic Variables

	Age	Education	Household Size	Income	Sex	Distance From Madelia
Average Value	58.8 years	15.024 years	2.68 people	$78,771	68.8% Male 31.2% Female	77.54 miles
Range	27-97 years	8-19 years	1-8 people	$0.00 - more than $100,000	Male or Female	50.4 - 91.6 miles

Table 2 (continued)

	Property Value	Rent	Marriage Status	Employment	Farmland Ownership	Fraction of Income from Farming
Average Value	$292,622	$738.02	73.01% Married, 9.66% Single, 9.81% Widowed, 7.50% Divorced	51.93% Full Time, 9.87% Part Time, 6.72% Not Currently Employed, 31.47% Retired	93.98% None, 2.58% Own and Operate, 3.01% Own and Rent Out, 0.43% Lease from Others	0.98%
Range	$0.00 - more than $1,000.000	$0.00 - more than $1,500.00	Married, Single, Widowed, Divorced	Full Time, Part Time, Not Currently Employed, Retired	None, Own and Operate, Own and Rent Out, Lease from Others	0%-100%

Table 3: Average Interest in Recreational Services

	Hunting	Biking	Picnics	Hiking	Bird Watching	Photography
Average Interest	1.26	2.17	2.15	2.45	1.92	1.81
	Nature Walks	Wildlife Viewing	Camping	Horseback Riding	Nature Viewing	
Average Interest	2.49	2.54	1.74	1.17	2.36	

Note: The range of interest for all recreational services is from 0 (Not Interested) to 5 (Extremely Interested).

Table 4: Average Rank of Environmental Services

	Clean Water for Recreation	Safe Water for Drinking	Reduced Flooding/High Flows	Increased Plant Biodiversity
Average Rank	3.37	1.94	3.83	4.50
	Increased Animal Biodiversity	Global Climate Change Mitigation	Increased Green/Open Space	
Average Rank	4.32	4.25	4.12	

Note: The ranking scale for all environmental services is from 1 (Most Important) to 7 (Least Important).

Further analysis will be conducted to determine the strength each demographic variable or recreational service will have on a respondent's WTP and the number of visits a respondent would make to a recreational area. For example, Equation (1) will test the strength of each variable in explaining WTP for each respondent, denoted as i, before or after the perennial grass conversion:

$$WTP_i = \beta_{0i} + \beta_{1i}rec + \beta_{2i}age + \beta_{3i}educ + \beta_{4i}hhsize + \beta_{5i}inc + \beta_{6i}sex + \beta_{7i}dist \quad (1)$$

where rec represents whether or not a participant is interested in a recreational opportunity, visit is the number of visits to a recreational area in Madelia, age denotes the respondent's age in years, educ represents the number of years of education, hhsize is the number of people living in the respondent's household, inc represents the respondent's 2008 gross household income, sex indicates male or female respondent, and dist is the distance in miles the respondents live from the Madelia area based on zip codes. The recreational opportunities include hunting, biking, picnics, hiking, bird watching, photography, nature walks, wildlife viewing, camping/overnight stays, horseback riding, and nature viewing. As shown in Table 3, wildlife viewing, hiking, nature walks, and nature viewing were the most favored activities.

C. Revised Process Flow Diagram for Life Cycle Assessment

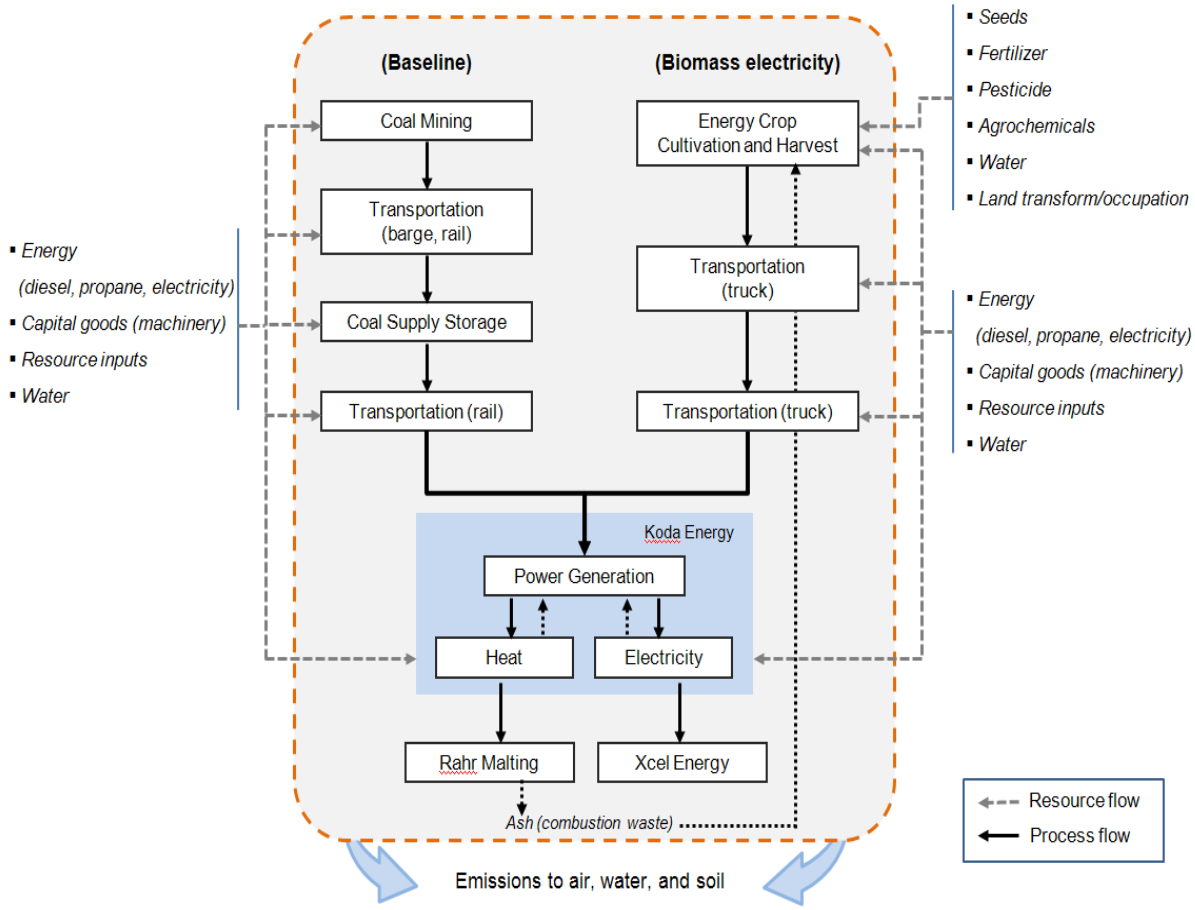

Figure 1. Revised process flow diagram of baseline (a), and dedicated biomass electricity production system (b)

D. Bio-baler Demonstration Report

"Demonstrations of the FLD Biomass Technology Bio-baler in Minnesota"
FINAL REPORT
April 30, 2010

Background

In the last several years, interest has grown in the production of energy from renewable sources to address our dependence on foreign oil and address issues of climate change due to emissions of carbon dioxide into the atmosphere. Minnesota, with its agricultural regions in the southern and northwestern parts of the state and forestlands in the northeast has the potential to produce biomass that can be used for renewable energy from dedicated woody crops for energy, brushland clearing, and removal of hazardous fuels from forest areas and even from the efforts to eradicate invasive species. That potential is limited by the ability to efficiently and cost effectively remove that biomass from a site and deliver it to a facility that can use it to produce energy. Logging equipment is designed for sawlogs and pulp sticks but often ill suited to the removal of the woody biomass being proposed for energy which is usually smaller diameter material.

To address the issue of smaller diameter woody biomass harvest for energy manufacturers have responded by developing equipment designed for that purpose. A piece of machinery that holds promise for that purpose is the FLD Bio-baler, now in its third generation of development. The baler offers several advantages over other equipment that has been proposed. The baler is relatively inexpensive, produces bales that can air dry for a period of time before utilization, is able to maneuver in forests and on uneven ground, and is able to harvest dedicated woody crops, brushlands, and forest understory.

The National Forest Service, DNR and Minnesota counties currently pay operators to remove hazardous fuels from forest areas and woody biomass from brushlands to favor bird habitat and maintain grasslands. That material is burned or left to deteriorate but could have a market outlet if gathered and used for bioenergy. The sale of that biomass would also help offset the costs of those management operations, lowering their cost or generating a profit allowing those agencies to use the money saved for other management priorities. In the process this activity has the capacity to generate employment and income and offer an additional opportunity to the logging companies in Northern Minnesota.

The Center for Integrated Natural Resources and Agricultural Management (CINRAM) and the Dept. of Forestry at the University of Minnesota have been following the development of the bio-baler and negotiated with the manufacturer to bring the machine to Minnesota to demonstrate its use to natural resource professionals who currently manage brushland habitats, the forest industry and specifically forest land managers and loggers, as well as other groups and individuals interested in dedicated woody crop production, wildlife habitat maintenance, and forest fuel management. The manufacturer agreed to bring the equipment to Minnesota for a series of demonstrations with the costs covered by a consortium of agencies, NGO's, development organizations and with a generous contribution from the Initiative for Renewable Energy and the Environment.

Objective:

The objective of the demonstrations was to provide contractors, natural resource professionals, land managers and others the opportunity to see this particular piece of equipment in action and evaluate it in terms of the needs we have in Minnesota for harvesting biomass for energy.

Note: Parallel to the demonstrations, the University of Minnesota and our Canadian partners gathered information on the performance and costs of the equipment and the amount of material produced on each of the demonstration sites.

Activities undertaken:

1. **Demonstration of the Bio-baler**: The demonstration was carried out on 8 sites throughout Minnesota (see attached schedule) including: a) harvest of short rotation woody crops (willow, poplar) in Waseca; b) brushland harvest in southern Minnesota agricultural regions; c) invasive species harvest in the Metropolitan area; d) brushland harvest in northeastern Minnesota; and e) aspen thinning to improve forest productivity in northeast Minnesota.
2. **Question and answer period with Bio-baler developer and operators**: On every site, the bio-baler developer and operator were available for questions from those attending following the demonstration.
3. **Gather data on costs and production**: CINRAM, the equipment manufacturer and the University of Laval in Canada took data on existing biomass volume on the sites prior to harvest, and the productivity and performance of the biomass baler.

General Results

The 8 demonstrations were completed very satisfactorily with a lot of interest demonstrated by participants. The machinery was able to keep to the planned schedule and perform the harvesting with a minimum of technical problems. Minor adjustments were made to machine due to the wide variety of sites and vegetation types that were included in the demonstrations. It is fair to say that the Minnesota demonstrations provided the greatest diversity of site and species conditions that the bio-baler has been tested on. Some general information on the demonstrations:

- Over 200 people attended the bio-baler demonstrations and participants included agency personnel (exs. DNR, USFWS, Mn/DOT), research organizations (UMN Forest Resources, Applied Economics, NRRI, Extension service), NGO's (Rural Advantage, Nature Conservancy), private contractors who do biomass removal and forest harvest and machinery dealers, environmental engineers, entrepreneurs among others.
- The response to the bio-baler was favorable for the most part. The USFWS and DNR wildlife people as well as the Grouse Society showed the greatest interest in the bio-baler for its application for wildlife habitat improvement. Recently the Deer Hunters Association in Minnesota helped sponsor a follow-up demonstration.
- Since the demonstration in September, Stempower, USA, a Minnesota start-up company, has purchased a bio-baler and is contracting brushland harvest primarily for wildlife habitat improvement.

- Results of the research will be presented in Quebec City, Canada at the 17th World Congress of the International Commission of Agricultural and Biosystems Engineering in July of 2010. For detailed results of the demonstrations please contact: Dean Current, CINRAM, curre002@umn.edu, 612-624-4299. A video summary of the demonstrations is also available upon request.

Summary

The bio-baler demonstration represents a highly leveraged investment of IREE funding that included contributions from a broad range of partners from the academic, public and private sectors. The demonstrations were implemented with a great amount of interest demonstrated by participants. A direct impact of the demonstration has been the purchase of a bio-baler by a local company that is specializing in biomass harvest. Besides that specific application, research data has been generated and analyzed to help determine productivity and costs of the machine and will be used to make improvements in the technology.

Note: A copy of the bio-baler schedule has been included as an attachment to this report

Harvest of woody crops with a bio-baler in eight different environments in Minnesota

Authors: Philippe Savoie, Dean Current, Pierre Luc Hébert, François-Simon Robert, Peter Gillitzer

Summary of findings

The bio-baler is a alternate approach to harvest woody crops in the form of a round bale. The machine is a reinforced agricultural round baler with a robust cutter-header designed to cut, shred and feed woody stems into the compression chamber. Originally developed in 2006 to harvest short-rotation willow in level plantations, the bio-baler has since been modified to work on rough terrain and harvest a wide range of woody crops with a basal diameter up to 100 mm at the point of cut and heights up to 6 m. The bio-baler is therefore a potential new tool to manage wild brush, forest understory vegetation, small trees on abandoned agricultural land, in addition to its original role to harvest young planted trees. The round bale format (typically 1.2 m wide by 1.5 m diameter) allows easy handling, storage and transport to a site where the biomass can be used for energy or other applications. In fall 2009, a third generation bio-baler was used on eight different sites across Minnesota (Waseca, Madelia, Faribault, Afton, Ogilvie, Hinckley, Aurora and Hibbing). A total of 160 bales were harvested at the different sites over eight days. Average bale mass was 466 kg (minimum of 403 kg; maximum of 528 kg). Bale density averaged 296 kg/m³ (min. 204 kg/m³; max. 388 kg/m³). Moisture content of the biomass averaged 44.9% (min. 36%, max. 51.3%). Average bale dry matter density was 163 kg DM/m³. From the eight sites, a total of 75 tonnes of green biomass was harvested over 5 hectares. Harvested biomass per unit area averaged 14.72 t/ha; it ranged from 2.49 t/ha on very lightly covered land to 55.24 t/ha on densely covered land. Pre-harvest yield was estimated on some sites so an estimate of biomass recovery was available. For example, 72.3% of original biomass (cottonwood) was harvested in Madelia; 75.8% of original biomass (oak and maple small trees) was recovered in Afton; 73.5% of poplar regeneration was recovered in Hibbing. Actual harvest rate averaged 17.40 bales/h (min. 2.31 bales/h; max. 34.22 bales/h). Mass harvest rate averaged 7.78 t/h (min. 1.22 t/h; max. 14.20 t/h). Harvest rate was higher in dense vegetation where the bio-baler could fill its chamber more quickly and over a short distance. Fuel consumption for the harvest operation (diesel engine tractor) averaged 1.75 L/bale (min. 0.52 L/bale; max. 4.74 L/bale). Fuel consumption per bale was lowest when harvesting in dense vegetation. The data will be useful to estimate the cost of harvesting woody biomass with a bio-baler under a wide range of environmental conditions. This will allow comparing the bio-baler with alternate biomass removal techniques in a perspective of improved land management and biomass recovery.