

UNIVERSITY OF MINNESOTA

Twin Cities Campus

*Center for Integrated Natural Resources and
Agricultural Management*

*College of Food, Agricultural and
Natural Resource Sciences*

*107 Green Hall
1530 Cleveland Avenue North
St. Paul, MN 55108-6112*

*Office: 612-624-4299 or
612-624-7418*

Fax: 612-625-5212

<http://www.cinram.umn.edu/>

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

Contract Number: RD3-1

Milestone Number: 1

Report Date: June 12, 2009

Principal Investigator: Dean Current

612-624-4299

curre002@umn.edu

Contract Contact: Bridget Foss

612-624-5571

foss0134@umn.edu

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

Since many energy crops under consideration are relatively new and do not have the large research base associated with commodity crops, there is a need for research on their production, processing, and delivery to energy facilities. Basic agronomic research is needed to determine the most cost effective cultural practices required to produce crops at a price competitive in the market and which provides good income potential for landowners. Research is needed on establishment practices, optimum planting and harvesting dates, as well weed control practices. As management practices are better understood both productivity and cost effectiveness will improve providing lower costs for biomass energy feedstocks. Another promising area of research which can help lower the cost of biomass feedstocks to energy facilities are the emerging markets for environmental services.

The University will look at the entire system from production of feedstock to address current constraints in developing a biomass feedstock supply chain that is able to effectively deliver biomass to an energy producing facility. Issues addressed include pre-processing, storage, and transportation of a low density feedstock. The analysis will include a life-cycle analysis component carried out by an expert in that field to specifically address issues of energy balance and integration of diverse environmental benefits. Throughout the supply chain we will measure costs to estimate the delivered cost of bioenergy feedstocks. To that cost analysis will be added a component for a system of payments for the diverse environmental services provided by plantings.

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

This series of activities will help us understand issues in producing biomass crops on farm from planting through harvesting. Since many of the crops being considered for biomass production, and especially some of the native prairie species have not been produced commercially knowledge of production is limited to what is known about reestablishing prairies but not with commercial production in mind. We need to understand how to produce these new crops and how to manage them throughout the growing season through harvest. The objective of Research Area I is to develop guidelines for production of biomass that can be provided to farmers.

Experiment 1: Establishment strategies for weed control

Objectives: Develop new approaches for weed control in establishing native perennial grasses and grass-forb polycultures.

Experimental design: Randomized complete block with 4 replications. Treatments will be in a split plot arrangement.

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 are 1) oat and barley companion crops, 2) herbicides specific for weed control in native grasses or forb mixtures, 3) a cool season native grass with high seedling vigor (Canada wildrye), and 4) a mowed control.

Specific methods:

Establishment: completed for 2009; repeat for 2010

Whole plots were established in 30 by 50 ft blocks Seeding rates of all species as per recommendation of the University of Minnesota. All treatments were seeded in May. Grass plots will be fertilized with 80 lb N/acre each year beginning in the year following establishment

Data to be collected in 2009

- 1) Plant populations of all treatments in June and September of the year of seeding and in spring of the year following seeding by counting all plants in a 3 ft² area.
- 2) Biomass yield in the late fall of the seeding year; in the fall for three years after establishment. Biomass yield will be determined by harvesting a 10 by 10 ft² area to a 3 inch height within each plot. A subsample of 2000 g will be collected to a 3 inch height. Botanical composition (weeds, native grasses, and forbs) and contribution to dry weight will be measured. The subsample will be dried and yield expressed on a dry matter basis. The energy value of the biomass will be determined using bomb calorimetry.

Accomplishments:

- I. **Experiment 1. The experiment was established as indicated above and appropriate data will be collected in 2009 as described.**
- II. **A larger field scale planting of the whole plot treatments (Switchgrass grown alone, a native grass tertiary mixture of switchgrass, big bluestem, and indiangrass, and a mixture of switchgrass, big bluestem and indiangrass with four native forbs and four native legumes) was conducted in 2008 in cooperation with Rahr Malting using only a barley companion crop. Data will be collected in 2009 as indicated above.**

Experiment 2: Optimum planting dates for native perennial crops

Objectives: Determine the effect of planting date on the establishment of native perennial grasses and grass-forb polycultures.

Experimental design: Randomized complete block with 4 replications. Treatments will be in a split plot arrangement.

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 will be three dates of seeding: Early December before snowfall; January-March; and June.

Specific methods:**Establishment**

Plots were 5 by 5 ft and were broadcast seeded. Seeding rates of all species will be based on recommendation of the University of Minnesota. Weeds will be controlled using best management practices including herbicides.

Data to be collected in 2009

- 1) Plant populations of all treatments in September of the year of seeding and in spring of the year following seeding by counting all plants in a 3 ft² area.
- 2) Biomass yield in the late fall of the seeding year; in the fall for three years after establishment. Biomass yield will be determined by harvesting a 3 by 3 ft² area to a 3 inch height within each plot. A subsample of 2000 g will be collected to a 3 inch height. Botanical composition (weeds, native grasses, and forbs) and contribution to dry weight will be measured. The subsample will be dried and yield expressed on a dry matter basis. The energy value of the biomass will be determined using bomb calorimetry.

Accomplishments:

The experiment will be established in December 2009 as indicated above and appropriate data will be collected as described.

Experiment 3: Optimum harvest dates for native perennial biomass crops

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. Treatments will be in a split plot arrangement.

Whole plot treatments will be 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 will be four dates of harvest: September, December, March, May (before greenup)

Specific methods:

We will utilize established stands of natives located at two locations. The stands established in Experiment 1 are not fully developed.

Data to be collected

- 1) Biomass yield at each target harvest date for three consecutive years. Biomass yield will be determined by harvesting a 3 by 3 ft² area to a 3 inch height within each plot. A subsample of 2000 g will be collected to a 3 inch height. Botanical composition (weeds, native grasses, and forbs) and contribution to dry weight will be measured. The subsample will be dried to allow yield expression on a dry matter basis. The subsample will be analyzed for nitrogen and mineral (P, K, Mg, MN, B, S, Si, Na) concentration. The energy value of the biomass will be determined using bomb calorimetry.

- 2) Plant populations of all treatments will be measured each spring in June during green-up of the stands. All plants will be counted in a 3 ft² area.

Accomplishment:

Harvest date experimentation will begin this summer of 2009. We have laid out field design and located stands of native plants. We are completing analysis of a preliminary study with switchgrass.

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 the Koda Power facility just went on line. They are currently not burning native grasses. A test burn will occur this summer and we can begin ash characterization. Actual ash application will not occur till the characterization is completed. Projected date of first application is in spring 2010.

II. Moving biomass from road/farm gate to facility

This will be undertaken by Koda Energy, will be initiated prior to project start date, and will not require Xcel Energy RDF funding as this is part of their commercial operations. Progress on this area will be reported in future milestone reports.

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.

Wildlife impacts

Overview of 2008-2009 Accomplishments

Gamebird surveys were selected as the most practical and easily measured indicator of wildlife impacts of bioenergy plantings. Gamebird surveys were initiated in the spring.

Planned Activities for 2009-2010

Gamebird surveys will be repeated in the spring of 2010.

Water quality assessment – Begin monitoring watershed

Overview of 2008-2009 Accomplishments

Monitoring of water quality and runoff from Elm Creek watersheds, tributaries to the Blue Earth River, have continued through 2008 into the spring of 2009. Monitoring of surface runoff and drain tile flow from two principally corn-soybean subwatersheds is accompanying monitoring of three watersheds with 16 to 24% of their areas consisting of perennial grass-wetland complexes. Stormflow, annual flow, nitrate-N, phosphorus, and total suspended solids (TSS) are being monitored at each location. Tile drains from replicated plots with woody and perennial herbaceous crops and corn-soybean crops continue to be monitored at the University of Minnesota Southern Research and Outreach Center in Waseca. The plot data provide responses of individual crop systems, whereas the watershed monitoring provide an integrated watershed response that would be similar to implemented bioenergy plantings in Minnesota farmland. Laboratory studies are underway to investigate phosphorus concentrations in water columns over soils with different P treatments. Water exchanges are being conducted to help explain P loading from perennial vegetation-wetland systems to contrast to loadings from annual croplands.

Planned Activities for 2009-2010

Monitoring data collected over the period 2005- 2009 will be analyzed and summarized to determine response of crops and watershed s with different percentages of perennial cropping. We will look at nutrient loading and rainfall-flow responses associated with different perennial crops (Waseca data) and contrast these with annual corn-soybean crops. Relationships between percentage of watershed under perennial grass cover and responses of flow and nutrient loading to rainfall events will also be analyzed. These analyses will used to develop modeling relationships for model calibration and testing to enable prediction of responses to changing vegetative cover on watersheds. Candidate models to be evaluated and tested with these data sets include the WET-HAWQ and SWAT models.

Integrated assessment of ecological service markets

Overview of 2008-2009 Accomplishments

The Ecological Services Team has met on a quarterly basis since the start of the project. To date the team has accomplished the following:

- Discussion of data to be gathered and methodology to be used.
- Two graduate students have been working on the project from Applied Economics and have produced a first draft of the survey instrument to be used.
- We have consulted with the UMN Center for Survey Research for assistance in survey development and obtaining lists to be used to select a sample for the survey.

Planned Activities for 2009-2010

Our priority areas of research as we move ahead include:

- Finishing up the survey instrument, testing it and applying it over the summer months and into the fall as needed.
- Analysis of the survey results.
- Preparation of a report of the results by the end of 2009

Life cycle assessment (See Appendix 1)

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.

Cost Benefit Analysis – Plan activities and begin data collection

Overview of 2008-2009 Accomplishments

Researchers in the Department of Applied Economics have recently published data on the costs of the production of a variety of biomass crops for energy. We will be using that data but also developing a plan to gather data over the summer from other sources (SWCD's, DNR, NRCS, other University researchers and others) to compare with the published data.

Planned Activities for 2009-2010

We will be gathering data over summer and fall, 2009 from agencies and past planting projects and other sources listed above to refine the published data. We will give preference to data that best reflects larger field plantings similar to what we would expect to be put in to serve a biomass facility such as the KODA project. The data to be gathered will include:

- 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 need to be integrated with the data being developed through the planting and cultivation experiments.

Valuation of ecological services

Overview of 2008-2009 Accomplishments

This will be done in coordination with **IV** above. Results from IV 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. Linda Meschke is involved in a project which is studying payments for environmental services in the Minnesota River Basin and Dr. Bill Easter and Dr. Dean Current on our team have been named to the National Advisory Committee for that project which will provide another source of information for this work.

Planned Activities for 2009-2010

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

Appendix 1 – Life Cycle Assessment Plan

Initially, the Life Cycle Assessment was not planned to be initiated until later in the project. Because of the importance of close coordination between the LCA team and the other research groups to be able to gather the appropriate data for LCA we initiated LCA activities earlier. Following is a description of that program, progress and plans.

A. JUSTIFICATION OF LIFE CYCLE ASSESSMENT (LCA)

More than 4 trillion kWh electricity is consumed within the United States each year (EISA 2008), and the demand has been projected to increase. To satisfy the demand, coal accounts for over 50% of power generation fuels, by which 87% of all coal production in the US is consumed. The conventional coal-fired power generation process emits considerable amounts of SO₂, NO_x, CO₂, CO and particulate matter. Countries including the US, Japan, and Germany have made efforts to reduce emission through technology modification and policies re-enforcement in order to minimize environmental impacts while assuring electricity supply (Millan et al. 2008; Popp, D. 2006).

To reduce the environmental impacts associated with the power generation, one of the often-mentioned approaches is to seek alternative renewable energy sources such as dedicated perennial crops. One study claimed that biomass, if co-fired with coals, can decrease overall CO₂ and SO₂ emissions due to its low carbon and sulfur contents. In addition, lower NO_x emissions are reported since biomass is volatile and contains lower amounts of fuel-bound nitrogen (Tillman D. 2000).

However, the new combining approach should be carefully examined throughout the entire life cycle of power generation from material mining (feedstock production) to waste disposal. Previous studies (Tillman D. 2000; Demirbas, A. 2003; Sami et al. 2001) estimated environmental impact reduction from co-firing technology by analyzing biomass chemical compounds instead of conducting the holistic study. The environmental performance is still questionable because emission from required processes associated with the biomass technology for energy production, including biomass transportation, collecting or any type of preprocessing, are not taken into account. Furthermore, only limited categories of biomass, such as wood chips, saw dust, and switchgrass, have received attention in similar studies. Therefore, our LCA study aims to determine the environmental benefits of energy production with the major dedicated energy crops as a feedstock in power plants. The analysis will employ the life cycle assessment to incorporate a systematic approach, in which the environmental impacts associated with the relevant processing stages of power generation from field (cradle) to energy production at power plants (gate) will be taken into account.

B. GOAL AND SCOPE

Corn stover is the remaining parts of corn plants left in the field after corn is harvest. In the US, the average corn production from 2005 to 2007 was 13 billion bushels per year (USDA 2008) and the estimated corn stover production amounted up to 330 million metric tons per year. This figure implies approximately 148 metric ton of surplus corn stover was wasted beyond the amount needed for soil conservation.

In LCA study, the environmental benefits of energy production with dedicated energy crops will be measured by conducting the life cycle analysis (LCA) based on supply chain scenarios by a type of feedstock as specified in ISO 14040 guidelines. The magnitude of the environmental impact of each scenario-based energy production system is quantified and evaluated by comparing it with a baseline system using solely coal-fired energy production.

1. Functional unit

The main focus of LCA study is the environmental impact of electricity production, and 1 kWh of electricity production in the power plant is selected as the functional unit for the comparison of energy production scenarios.

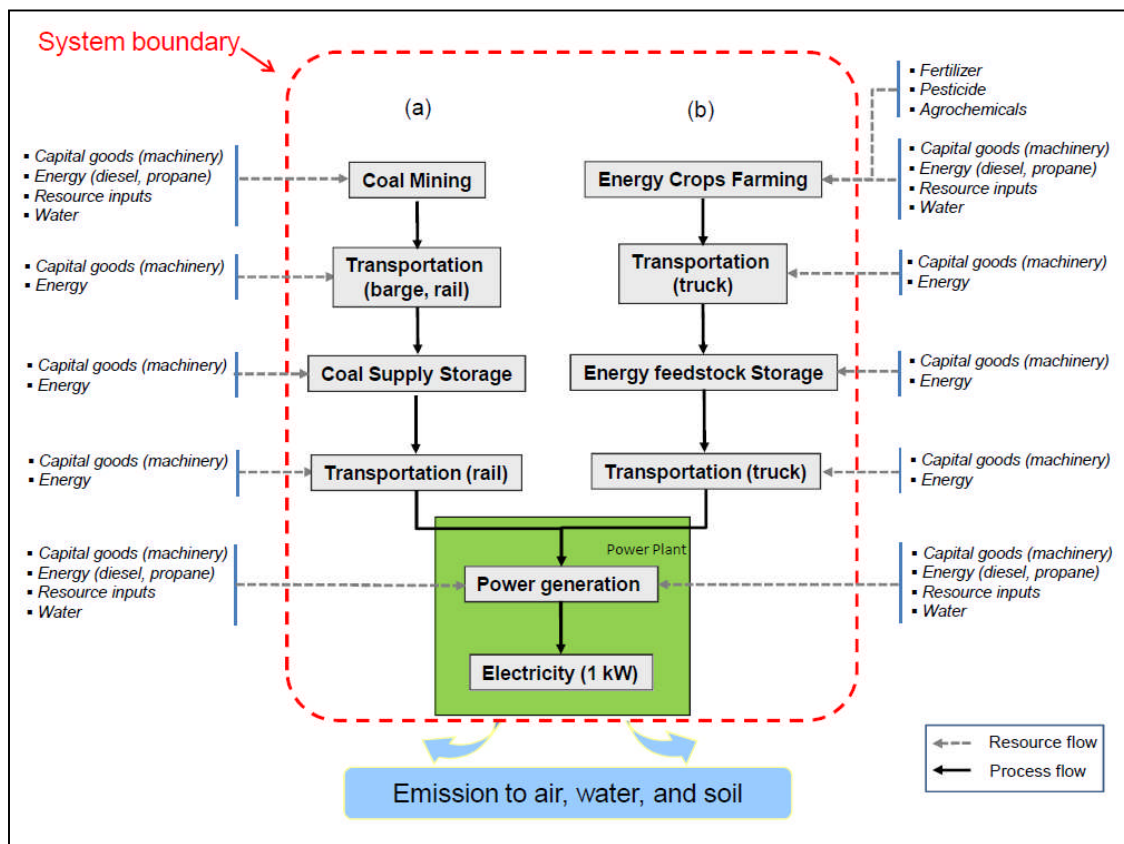


Figure1. Schematic process flow diagram of conventional coal energy production system (a), and dedicated biomass energy production system (b).

2. System boundaries

To conduct life cycle inventory analysis (LCIA) precisely, the initial system boundaries for this life cycle inventory (LCI) analysis confines all the staged from the material extraction (feedstock production) to the electricity generation. Initial system boundaries are set up to include all the material flows, energy flows and emissions. When feedstock materials arrive at the power plant, they are either further mixed based on the designed mass ratio or combusted for converting heat into electricity.

The system boundaries, therefore, are drawn to include the key processes of materials extraction (i.e. coal) or feedstock production (i.e. perennial crops), transportation to storage, storage, storage to power generation facilities and electricity generation. The manufacturing of materials other than coal and energy crops used within the systems is excluded from the initial system boundary. For example, fertilizers, water, and diesel fuel as energy input, are generated from other intermediate processes and listed as direct inputs to the studied systems. These materials are transported from the regional storages to the processes where they are used.

3. Data collection and requirement

Three categories of data are required to identify and compile the LCI, including:

- Energy and material inputs to and outputs from the systems;
- Capital goods as inputs to the systems (tractor, truck, and other infrastructure);
- Environmental emissions such as total greenhouse gas emissions of GHGs (as CO₂ equivalents) and emissions commonly monitored air contaminants (NO_x, SO_x, PM₁₀, CO, etc.).

Thus, for each unit process associated with the studied system, each type of data is being collected accordingly. In the energy and material inputs category, fuels for transportation and electricity were considered as primary energy inputs in the studied systems. The list of the primary inputs, units, and data sources by each process is shown as Figure 1. For each unit process, air emission, water emission, and solid waste were investigated and compiled.

The software, CMLCA, is the primary analysis tool in this study. Main data sources used in this study included the US Energy Information Administration (USEIA), the National Renewable Energy Laboratory (NREL), the US LCI database, and EcoInvent. However, compared with EcoInvent dataset, the US LCI dataset contains less of what is required in this study, and data gaps are expected when converting the Europe-oriented database (EcoInvent) into the study which focuses on the US only. All data mined from EcoInvent were validated based on US LCI database. All resource and energy inflows/outflows, environmental resources, and emission were recalculated or rescaled. The inventory data were modified when the difference of each inventory between these two groups of data exceeded 5% of what was estimated in the US LCI dataset. In addition, if data cannot be found in EcoInvent or US LCI, numbers were adjusted and estimated based on the literature review.

C. LCA study schedule

Task	2009				2010				2011				2012				1 3
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
Goal and scope definition - Functional units - System boundary - Data category and requirement																	
Life Cycle Inventory (LCI) - Determine and refine energy production scenarios - Inventory database compilation for baseline energy production system																	
Life Cycle Impact Assessment (LCIA) - Categorization and characterization of LCI results - Normalization																	
LCAs for alternatives - LCI and LCIA for alternative scenarios																	
Life cycle interpretation - Sensitivity analysis of the LCA results of all scenarios - Completeness check of the results - Consistency check of the results																	
LCI database development - Annual reports - Final report																	

D. References

1. EIA 2008. *Electric power annual 2006*.
(http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html)
2. Millman, A., Tang, D., and Perera, F. 2008. Air pollution threatens the health of children in china. *Pediatrics* 122, 620.
3. Popp, D. 2006. International innovation and diffusion of air pollution control technologies: The effects of NOx and SO2 regulation in the US, japan, and germany. *Journal of Environmental Economics and Management* 51, 46-71.
4. Baxter, L. 2005. Biomass-coal co-combustion: Opportunity for affordable renewable energy. *Fuel* 84, 1295-1302.
5. Tillman, D.A. 2000. Cofiring benefits for coal and biomass. *Biomass and Bioenergy* 19, 363-364.

6. Tillman, D.A. 2000. Biomass cofiring: The technology, the experience, the combustion consequences. *Biomass and Bioenergy* 19, 365-384.
7. Demirbas, A. 2003. Sustainable cofiring of biomass with coal. *Energy Conversion and Management* 44, 1465-1479.
8. Sami, M., Annamalai, K., and Wooldridge, M. 2001. Co-firing of coal and biomass fuel blends. *Progress in Energy and Combustion Science* 27, 171-214.
9. USDA 2008. *National agricultural statistics service*. (<http://www.nass.usda.gov/>)
10. NREL 2009, U.S. Life Cycle Inventory database. (<http://www.nrel.gov/lci/database/>)
11. Swiss Centre for Life Cycle Inventories, Ecoinvent Database. (<http://www.ecoinvent.ch/>)

Project Status: The project has a good start with progress in most areas

LEGAL NOTICE

THIS REPORT WAS PREPARED AS A RESULT OF WORK SPONSORED BY NSP. IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF NSP, ITS EMPLOYEES, OR THE RENEWABLE DEVELOPMENT FUND BOARD. NSP, ITS EMPLOYEES, CONTRACTORS, AND SUBCONTRACTORS MAKE NO WARRANTY, EXPRESS OR IMPLIED, AND ASSUME NO LEGAL LIABILITY FOR THE INFORMATION IN THIS REPORT; NOR DOES ANY PARTY REPRESENT THAT THE USE OF THIS INFORMATION WILL NOT INFRINGE UPON PRIVATELY OWNED RIGHTS. THIS REPORT HAS NOT BEEN APPROVED OR DISAPPROVED BY NSP NOR HAS NSP PASSED UPON THE ACCURACY OF ADEQUACY OF THE INFORMATION IN THIS REPORT.