Conservation Innovation Grants
Final Progress Report

Agreement Number: *68-3A75-6-156*
Grantee Name: *K.E. Ileleji (PI), D.E. Maier (Co-PI), D. Ess (Co-PI)*
Project Title: *Exploring Biofuel Alternatives for Energy-Intensive Seasonal Drying Processes*
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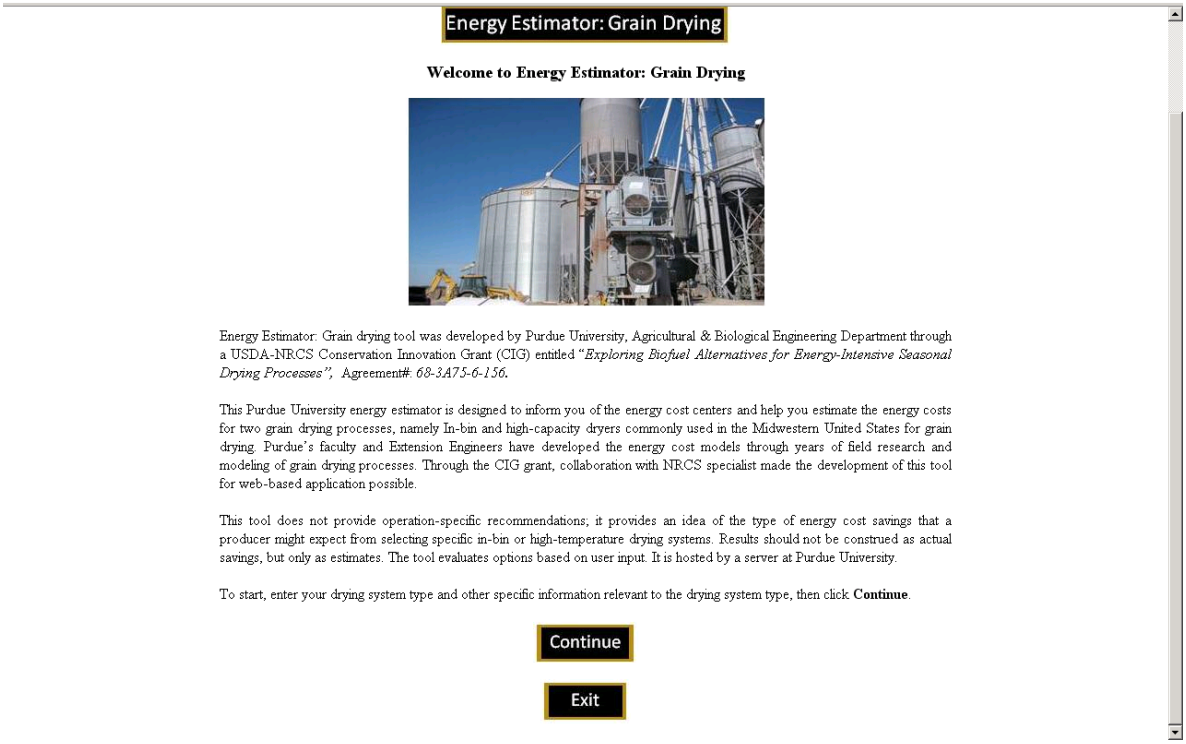
Period Covered by Report: *July 2007 – December 2010*
Project End Date: *12/31/2010*

Summarize the work performed during the project period covered by this report:

Launching of Energy Estimator Tool On-line: In early September, the Purdue Energy Estimator was launched to the public and became available online on Purdue Renewable Energy website at **http://www.extension.purdue.edu/renewable-energy**. It can be used by clicking on "On-Farm Efficiency." The energy estimator can be used to evaluate in-bin and high-capacity grain dryers. In-bin dryer users can calculate energy consumption and cost of drying various grain types (corn, wheat and soybean) using propane, natural gas or an electric heater. Users are able to select among 82 locations within the Corn Belt for which weather data is available on the system to simulate drying performance. Input data include grain type, fuel type, initial and target moisture content, drying start date, initial grain temperature, bin dimensions (diameter and height), grain price ($/bu), fan airflow rate (cfm/bu) and electric cost ($/kWh). The in-bin drying estimator calculates the fuel cost ($/bu), electric cost ($/bu), shrink cost ($/bu), drying time (days), average moisture, MBTU required and BTU/lb of water used for four drying strategies: natural air (NA), constant heat (CH), variable heat (VH) and self-adapting variable heat (SAVH). The front page of the Energy Estimator: Grain drying is shown on the next page.



Describe significant results, accomplishments, and lessons learned.

Grain Burner testing with Biofuels:

Studies on the combustion characteristics of No. 2 diesel fuel, soybean heating oil, biodiesel blends were successfully conducted using a grain dryer fuel burner modified to be compatible to these fuels. The main objective of this study was to analyze the effect of different blends of diesel and biofuels, used as alternative fuel source for grain dryer burners, on the composition of flue gas. A technical report of the test reporting the findings have been submitted to the Energy Team Leader, USDA-NRCS. The study showed that blends of No.2 diesel oil with Soy Heating Oil (SHO) or biodiesel making up to 20% by volume can be burned in grain dryer burners designed for fuel oil without significantly increasing combustion gas (CO, CO_2, NO, NO_2 and SO_2) concentrations. However, the dryer burners must be retrofitted with the compatible elastomers and fuel injection nozzles for optimum operation. A manuscript entitled *"A comparison of soy heating oil and biodiesel blends used as fuel in a grain dryer burner"* on this study is currently being revised for re-submission for a second review in Fuel journal. An extension paper will be prepared when the manuscript is finalized and has been accepted for publication.

Energy Estimator: Grain Drying.

In 2008, four Indiana producers which were assisted received USDA RD grant and/or loan funding totaling $164,815. In 2009, Purdue completed 82 audits for producers in seven states (IN, IL, MI, WI, MD, OH, and NY). Of these audits, 32 were funded with a total amount awarded at $1,126,139.41 in grants and $329,352.00 in loan guarantees to make energy efficiency improvements to grain dryers. If all 82 producers proceed with making the improvements regardless of USDA funding, we estimate they would collectively save over 162 billion BTUs of energy annually totaling $2,650,019.48, with an average annual savings of $35,333.59 per farm.

A significant outreach effort has taken place in the past 2 years to establish the energy auditing program within Indiana through partnering with the Indiana office of the USDA Rural Development and the Indiana Office of Energy Development. The Renewable Energy Extension Engineer (Dr. Ileleji) and Specialist (Mr. Martin) speak to various groups across the state about energy efficiency, and renewable energy development. These events have been used to promote Purdue's services along with the REAP and the state "Alternative Power and Energy" grant programs. Since early 2008, over ten workshops have been organized statewide to educate producers and rural small businesses about the REAP grant program. This has drastically increased the number of applications from Indiana, in addition to training grant writing professionals. ABE faculty and staff have utilized validated tools to simulate energy costs of various drying systems. These have served as a foundation for the newly created grain drying energy auditing service which as of January 1, 2010 operates on a fee for service basis. This service provides calculations on the annual energy savings and simple payback period from the producer's existing dryer to a new system, and provides them both a decision making tool, as well as a basis for providing technical information to apply for USDA-RD REAP funding. A summary of the program impacts are given below:

- Expanded ABE tools for energy simulation for grain drying systems into comprehensive energy auditing provided for producers applying to the USDA Rural Development REAP grant and loan program to make energy efficiency improvements.

- Provided workshop presentations at 11 programs statewide on the USDA REAP program in 2008.
- In 2008, eight energy audits were completed and four Indiana producers received either grant and/or loan funding totaling $164,815 from the Section 9006 program to replace their existing grain dryer to more energy efficient new systems.
- In 2009, **82** energy audits were completed by Martin for producers in seven states (IN, IL, MI, WI, MD, OH, and NY). Of these audits, 32 were funded with a total amount awarded at $1,126,139.41 in grants and $329,352.00 in loan guarantees to make energy efficiency improvements.
- If all 82 producers proceed with making the improvements regardless of USDA funding, we estimate they would collectively save over 162 billion BTUs of energy annually totaling $2,650,019.48, with an average annual savings of $35,333.59 per farm.

More recently, a total of 43 clients had be served with energy auditing service between December 1, 2010 and march 15, 2011. States represented – Indiana (22), Michigan (6), Kentucky (4), Ohio (3), elaware (2), Maryland (2), Missouri (2), Pennsylvania (1), Mississippi (1). The data on savings if the old dryers would be replaced by the new proposed dryers are given below:

- Total Annual BTU Savings – 75,358,728,767 BTUs
- Average Annual BTU Savings – 3,139,947,032 BTUs
- Average % Cost of Energy Savings – 37.67%
- Average % Energy Savings – 36.47%
- Total Annual Cost Savings - $1,305,306.00
- Average Annual Cost Savings - $54,387.00
- Total Project Costs - $8,499,561.00
- Average Project Costs - $354,148.00
- Average Payback Period – 7.72 years

Compare actual accomplishments to the project goals in your proposal:

Five objectives proposed in order to demonstrate, evaluate and transfer the use of alternative biofuels in grain drying systems for adoption by U.S. producers in the Midwest are given below:

1. Conduct a preliminary benefit-cost analysis to determine the economic desirability and environmental benefit of using biofuels (biodiesel and soy heating oil) for drying corn on Midwestern farms and elevators.
2. Develop a web-based energy auditing tool for grain drying systems
3. Modify and test biofuels (biodiesel/soybean heating oil) on a dryer burner with sufficient capacity to dry corn in a farm-scale column-type grain dryer available at the Purdue Post-Harvest Education & Research Center.
4. Analyze combustion gases for harmful pollutant emissions and dried corn for carcinogenic and other residues/grain quality from biofuel fueled burner.
5. Transfer the results of the demonstrated technology for adoption by U.S. grain producers and industry stakeholders through extension education and technology transfer activities.

Of these objectives proposed, Objectives 2 to 5 have been completed. For objective 3, only combustion tests using a test rig of a grain dryer with back pressure adjustment to simulate pressure drop of air through various grains was conducted. On-farm grain drying could not be done due to the lack of producer participants in the U.S because grain drying using fuel oil is not commonly practiced in the Midwest Corn Belt. We are still working to publish the results from this effort in a journal and also in extension briefs and papers. As was noted before, a manuscript entitled *"A comparison of soy heating oil and biodiesel blends used as fuel in a grain dryer burner"* on this study is currently being revised for re-submission for a second review in Fuel journal. The preliminary cost-benefit analysis (Objective 1) will be completed by the end of October 2011, and a manuscript on this topic will be prepared in the near future.

Describe the work that you anticipate completing after CIG funding:

We will keep using the Energy Estimator-Grain Drying Tool to help producers audit their grain drying systems for grant applications to the USDA-REAPS grants and loans program. We recently were awarded $93, 374 by the USDA-REAP for our proposed effort entitled *"Producer Assistance with Energy Audits of On-Farm Grain Drying Systems."* The grant also covers some of the expenses for conducting the audits, thereby providing producers a discount on the charge for their energy audits. The goal of this proposed effort is to assist producers by conducting comprehensive energy auditing and follow-up for the replacement of their existing grain drying systems which they may then use for REAP grant and loan funding applications. A comprehensive energy audit includes documentation of current energy usage and estimation of energy savings from alternatives grain drying and storage system options. The project will serve producers in multiple states throughout the U.S. In the 2010 funding cycle for USDA REAP funding, Purdue's Agricultural and Biological Engineering (ABE) Renewable Energy Extension program has assisted 166 producers in the states of Indiana (98), Illinois (24), Ohio (23), Michigan (10), Kentucky (2), New York (2), Missouri (2), Maryland (2), Minnesota (1), North Carolina (1), and Virginia (1). Other funding sources to sustain this effort will be pursued.

Manuscripts published or in review:

1. Jiru, T., B.G. Kaufman, K.E. Ileleji, D.R. Ess, H.G. Gibson, and D.E. Maier. 2010. Testing the performance and compatibility of degummed soybean heating oil blends for use in residential furnaces. *Fuel* 89 (1):105 - 113.
2. Ileleji, K.E., T.E. Jiru, D.R. Ess, and D.E. Maier. 2011. A comparison of soy heating oil and biodiesel fuel blends in a grain dryer burner. *In revision for second review*.

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