



The Conversion of Indigenous Agricultural Waste Feedstocks to Fuel Ethanol

**Cooperative Research and
Development Final Report**

CRADA Number: CRD-13-504

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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI, A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Ecopetrol America Inc.

CRADA Number: CRD-13-504

CRADA Title: The Conversion of Indigenous Agricultural Waste Feedstocks to Fuel Ethanol

Joint Work Statement Funding Table Showing DOE Commitment:

Estimated Costs	NREL Shared Resources
TOTALS	\$ 00.00

Abstract of CRADA Work:

Ecopetrol has set as one of its strategic goals the development of alternative energies, including achieving a production capacity of 450,000 tons of biofuels by 2015. Ecopetrol has partnered with the Colombian Petroleum Institute (ICP) to conduct research and to develop processes and technologies for converting lignocellulosic biomass into fuel ethanol and other biofuels. In support of this research, Ecopetrol released a Request for Quote (RFQ) in August of this year that focused on the biochemical conversion of agricultural waste streams to fuel ethanol. NREL's proposal was chosen to be funded and the parties have entered into negotiations on an agreement.

This CRADA is between NREL, a world leader in biomass conversion research, and Ecopetrol America Inc., Ecopetrol S.A.'s U.S. subsidiary. The research and development efforts described in the Joint Work Statement will take advantage of the strengths of both parties. NREL will use its Integrated Biorefinery Research Facility and vast experience in the conversion of lignocellulosic feedstocks to fuel ethanol to develop processes for the conversion of Ecopetrol's feedstocks. Ecopetrol will establish the infrastructure in Columbia to commercialize the conversion process.

The work will occur over 18 months starting in 2013, culminating in pilot-scale demonstrations using the most promising feedstock and conversion process in 2014 and 2015. The first phase of the project will be conducted at the bench scale and will focus on identifying the optimal pretreatment process and the best two out of three feedstocks for conversion. Phases two and three will focus on the optimization of the enzymatic hydrolysis and fermentation steps at the bench scale. Phase four is the integration of all of the unit operations and scale-up to pilot scale. As part of the project, Ecopetrol will fund NREL to conduct two (2) training courses for ICP personnel on lignocellulosic ethanol.

The benefits of this CRADA for the Department of Energy are many. 1) The project will create a strong collaboration between NREL and Ecopetrol in cellulosic ethanol, which will accelerate the development and deployment of biofuels in Colombia; 2) The work will result in expanding NREL's knowledge and experience in converting agriculture waste streams to biofuels; 3) Experimental and process data will be incorporated into a TEA model that will be used to validate the economics of the process, guide the experimental design of the product, and expand the NREL library of TEA models; 4) Ecopetrol has agreed to allow NREL to publish the results which will enhance NREL's international reputation; 5) If NREL performs well on this project, there is an opportunity for NREL to conduct another project with Ecopetrol in the area of thermochemical conversion.

Summary of Research Results:

Lignocellulosic ethanol lab-scale and pilot scale process development work in the Ecopetrol-NREL CRADA consisted of seven tasks. Activities in these seven tasks included compositional analysis of Colombian biomass feedstock, lab-scale and bench-scale pretreatment process development, lab-scale enzyme testing and enzymatic hydrolysis process development, lab-scale ethanologen strain testing and fermentation process development, a pilot-scale campaign of eight integrated pilot plant runs involving the unit operations of feedstock milling/pre-processing, pretreatment, enzymatic hydrolysis, fermentation, distillation, technoeconomic analysis, and a series of workshops/training sessions.

After significant lab-scale process development using Colombian biomass feedstocks was conducted in the areas of feedstock milling/pre-processing, pretreatment, enzymatic hydrolysis, and co-fermentation of mixed cellulosic sugars, the integrated process was scaled up in in NREL's Integrated Biorefinery Research Facility pilot plant. Eight integrated runs were completed, including ethanol fermentations both at 1,000 L scale and 6,000 L scale. The ethanol produced in these runs was recovered via distillation, with final concentration and dehydration conducted by an off-site contractor to produce about 700 kg of dehydrated ethanol, which was shipped to Ecopetrol's R&D facility in Bucaramanga, Colombia, for fuel testing purposes.

Additionally, significant amounts of data analysis and associated technoeconomic analysis of the results obtained in both the lab-scale and pilot-scale process development activities were conducted. This work was conducted in collaboration with Ecopetrol technical and management staff to identify potential business opportunities for potentially commercializing cellulosic ethanol technology in Colombia.

Work on these activities in the original CRADA has been completed and all associated deliverable reports have been provided to Ecopetrol. A small additional work-scope was added to the original CRADA to study the potential of an alternative mechanical refining pretreatment approach developed at NREL to the Ecopetrol feedstocks and processes. This work has also been conducted and the two deliverable reports associated with this work have been completed and provided to Ecopetrol.

Several manuscripts for publication of key results from the Ecopetrol-NREL CRADA in international peer-reviewed journals have been developed. These publications are proceeding through the journal acceptance process and are expected to be published in the coming months.

Subject Inventions Listing:

None

Report Date:

March 27, 2016

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