



Biomass Pyrolysis to Hydrocarbon Fuels in the Petroleum Refining Context

**Cooperative Research and
Development Final Report**

CRADA Number: CRD-12-500

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CRADA Report
NREL/TP-5100-70775
January 2018

Contract No. DE-AC36-08GO28308

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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI. Reports and Abstracts A.(3), of the Cooperative Research and Development Agreement (CRADA), 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: Petróleo Brasileiro S.A.

CRADA number: CRD-12-500

CRADA Title: Biomass Pyrolysis to Hydrocarbon Fuels in the Petroleum Refining Context

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
CY2014-CY2015	\$ 1,238,000.00
CY2016-9/30/2017 modified	\$ 1,562,000.00
TOTALS	\$ 2,800,000.00

Abstract of CRADA Work:

This work focuses on developing a thermochemical route to produce biofuels from agricultural wastes such as sugar cane bagasse, wood chips or corn stover; more specifically it intends to develop the biomass pyrolysis route, which produces bio-oils. Production of bio-oils by pyrolysis is a commercial technology. However, bio-oils are currently not being used for liquid fuels production. Although bio-oils can be produced by high-pressure liquefaction, pyrolysis is a less expensive technology. Nevertheless, bio-oils cannot be used directly as a transportation fuel without upgrading, since they are generally unstable, viscous, and acidic. Thus NREL and Petrobras intend to use their combined expertise to develop a two-step route to biofuels production: in the first step, a stable bio-oil is produced by NREL biomass pyrolysis technology, while in the second step it is upgraded by using two distinct catalytic processes under development by Petrobras. The first process converts bio-oil into gasoline, LPG, and fuel oil using the catalytic cracking process, while the second one, converts bio-oil into synthesis gas. Syngas gasification catalysts provided by both NREL and Petrobras will be tested.

The work includes experiments at both sites to produce bio-oil and then biofuels, life-cycle analysis of each route, personnel training and development of analytical methods with a duration time of two years.

NOTE: For logistical reasons—long time periods exchanging samples between the partners—the period was extended to four years and the scope concentrated in the catalytic cracking process using a commercial bio-oil from Ensyn Corp., the supplier selected by the CRADA partners. The large amount of bio-oils allowed Petrobras to generate significant quantities of coproduced fuels in Brazil. An Ensyn Corp. collaborator shipped coproduced samples to the United States for further hydrotreating and the production of gasoline and diesel containing pine bio-oil that met U.S. specifications and could obtain regulatory approval to enter U.S. commerce after successful performance testing. The second part of the work statement was deleted in favor of more industry relevant data.

Summary of Research Results and Applications:

The Petrobras/NREL CRADA international partnership successfully co-processed pine-based bio-oil with petroleum-based fuel intermediate oil in the fluidized catalytic cracking process (FCC), a common unit of a petroleum refinery. The finished fuels, containing renewable gasoline and renewable diesel, meet the same specifications as their fossil counterparts. These renewable/fossil fuels are the first refining co-processed fuels to receive U.S. Environmental Protection Agency (EPA) approval and to be used commercially in the United States.

Adding biomass-based fuels to the transportation mix increases the sustainability and security of fuel infrastructure while reducing air emissions and non-fossil carbon output in the United States and in Brazil. Being able to process those biofuels with fossil fuels in existing petroleum refineries considerably lowers overall development costs, uses the same distribution infrastructure, and hastens the addition of biofuels to the countries' fuel supplies.

Highlights:

- Co-processing 5% bio-oil is economically feasible in the near-term and 10% is possible with progress in industry and technology
- Low cost pathway for refiners to increase renewable content in current fossil fuel production using existing assets and minimal additional capital (~\$1 MM)
- Significant impact on techno-economics by lowering capital hurdle
- U.S. /global fluid catalytic cracking (FCC) capacities enable opportunity for several billion gallons of gasoline equivalent hydrocarbons containing biofuels
- CRADA is accelerating commercialization of this pathway in the United States, Brazil, Canada, the Netherlands, and other countries

Subject Inventions Listing:

None

Report Date:

29 September 2017

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