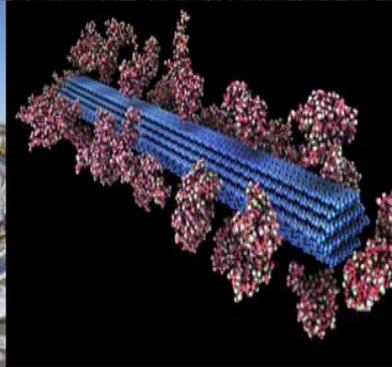




U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



Industry – Lab Success Stories

Advanced Development and Optimization (ADO) Workshop

Rick Elander and Josh Schaidle

December 12th, 2017

Feedstock Challenge



Partner: Ecopetrol (Colombia) 2013-2015

Challenge: Integrate regional mixed feedstocks for cellulosic ethanol into a sugarcane ethanol process



Ecopetrol/Bioenergy sugarcane ethanol production facility - Meta, Colombia

Market Opportunity:

- Light-duty fuel market is growing in Colombia; 1st generation sugarcane ethanol infrastructure being established
- Primary 2nd generation cellulosic feedstock (bagasse) is seasonal, but other regional feedstocks are available

Technology Opportunity:

- Develop appropriate conversion technologies for mixed cellulosic feedstocks with widely varied properties
- Evaluate integration strategies with sugarcane ethanol conversion process

Approach:

- Establish baseline conversion parameters for **two diverse feedstocks**
- Determine **conversion impacts at bench-scale** on several **mixed feedstock blend ratios**, based on business case scenarios established by Ecopetrol
- Perform a fully integrated **8 run pilot plant campaign** for selected business case scenarios
- Re-evaluate **TEA/business case opportunities** based on pilot plant campaign results
- Collaboration involved numerous **personnel exchanges** (meetings, workshops, researcher assignments, etc.)



Sugarcane Bagasse



Palm Rachis

Outcomes:

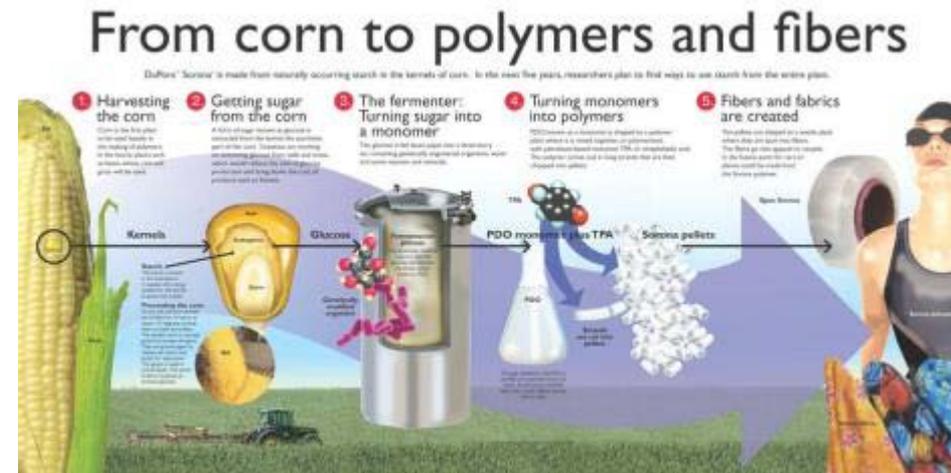
- Ecopetrol researchers and management team fully immersed in the technical and business challenges and opportunities of 2nd generation cellulosic ethanol
- Business cases established, including feedstock supply chain logistics/economics and required conversion performance, tied to fuel market considerations

Deconstruction/Upgrading Challenge



Partner: DuPont 2003-2008

Challenge: Develop and scale up a cellulosic ethanol deconstruction/upgrading technology package that met meeting DuPont's business case metrics and commercialization strategy



<http://sorona.com/>

Market Opportunity:

- Build off of successes of corn sugar-based commercialization of bio-1,3-PDO (Sorona®)
- Become an early technology provider for cellulosic ethanol from corn processing residues and corn stover

Technology Opportunity:

- Leverage NREL's core capabilities in pretreatment, enzymatic hydrolysis, fermentation, scale-up and techno-economic analysis
- Develop a business case supported by integrated small-pilot process data to warrant progression to a demonstration-scale facility

Deconstruction/Upgrading Challenge



Approach:

- Technology development in tandem at NREL and DuPont R&D facilities
 - Low-severity pretreatment
 - High-solids enzymatic hydrolysis
 - Improved ethanologen strains
- Modifications to NREL pilot plant facilities to enable integrated technology scale-up on all unit operations
 - Joint NREL-DuPont teams for all aspects of process design, equipment implementation, and operations



Demonstration Scale – Vonore TN



Commercial Scale – Nevada IA

Outcomes:

- Developed a technology package involving novel pretreatment, enzymatic hydrolysis and fermentation processes
- Completed a pilot-scale campaign that achieved performance and cost targets – led to demonstration plant

Partner: Johnson Matthey 2012 – present (CRADA)

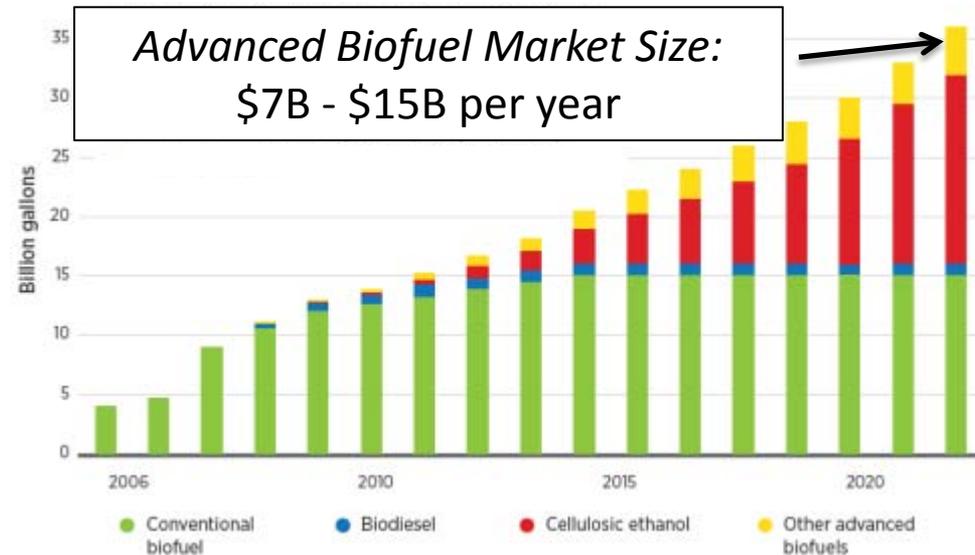
Challenge: Develop a biomass-to-fuels and chemicals technology based on catalytic fast pyrolysis and overcome technical hurdles to achieving high C yield

Market Opportunity:

- Relatively untapped advanced biofuel market
- Increasing renewable fuel requirements in Europe based on REDII
- Biomass processing represents new potential markets for Johnson Matthey catalytic materials

Technology Opportunity:

- Catalytic fast pyrolysis enables direct liquefaction of biomass to energy-dense liquids and chemical co-products, utilizing the whole plant
- Leverage national lab integrated biomass conversion facilities to evaluate catalytic materials from Johnson Matthey



Source: EPA, DOE Billion Ton Study

Deconstruction/Upgrading Challenge

Approach:

- Design and develop metal-modified zeolites by linking foundational science and applied engineering R&D
- Evaluate catalytic materials for CFP using NREL's 2" fluidized bed reactor and Davison Circulating Riser system
- Hydrotreat CFP oils to finished blendstocks at PNNL
- Evaluate fuel properties at NREL



CFP Oil



Hydrotreated Oil



Fuel Blendstocks

Outcomes:

- Demonstrated production of gasoline and diesel fuel blendstocks from clean pine feedstock using Johnson Matthey catalysts for CFP
- Identified technical hurdles that require further R&D to reduce commercialization risks
- Pursuing CRADA extension

Upgrading Challenge

Partner: Enerkem 2016 – present (TCF)

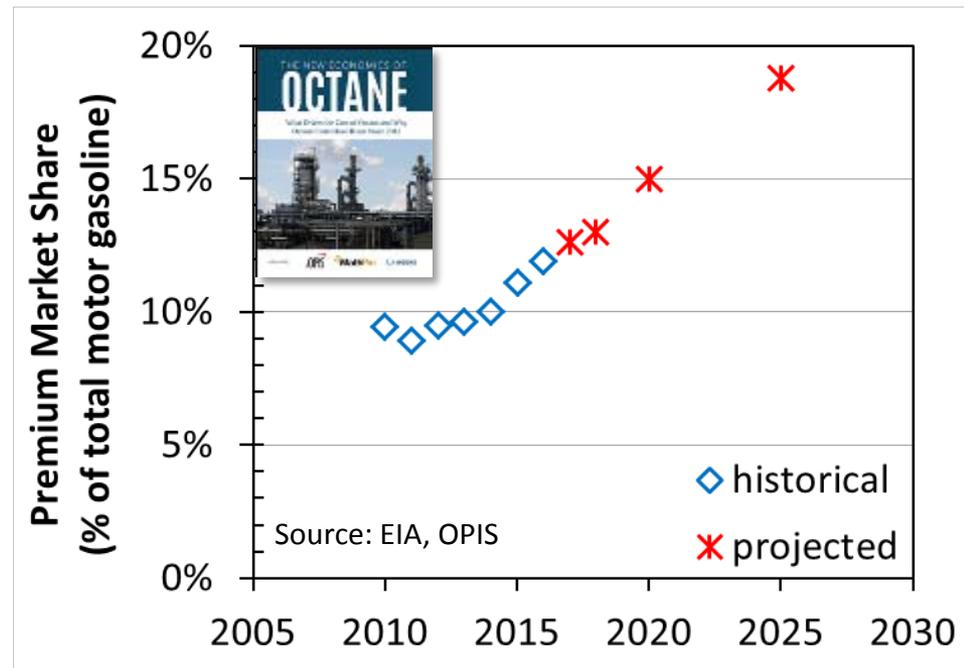
Challenge: Demonstrate extended time on stream production of high-octane gasoline blendstock from MSW-derived methanol at pilot scale

Market Opportunity:

- Increasing demand for premium gasoline
- Enerkem can take advantage of RFS credits if they can convert MSW-derived methanol into a gasoline blendstock

Technology Opportunity:

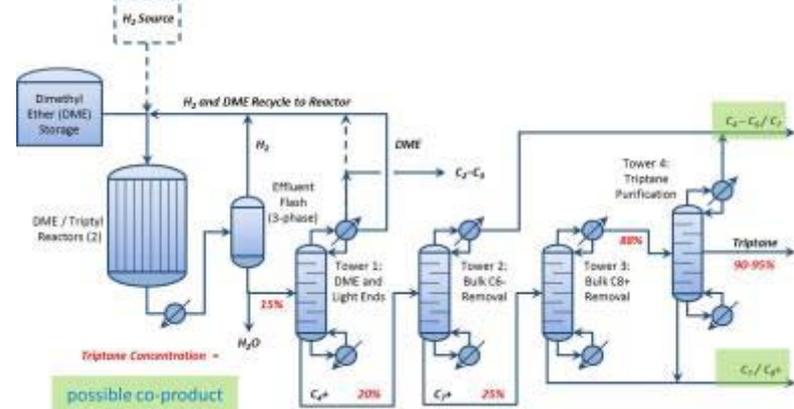
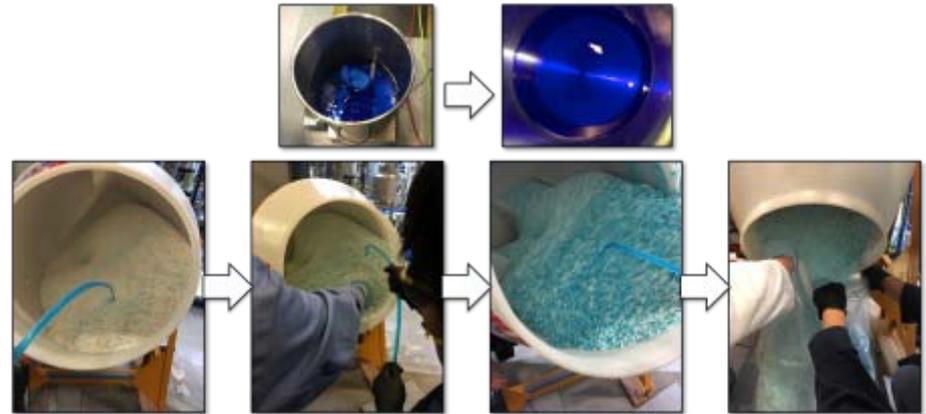
- Utilize NREL's patented catalytic technology for conversion of methanol/dimethyl ether into C₅-C₈ branched hydrocarbons at moderate temperature and pressure
- Demonstrate the technology at pilot scale at Enerkem's facilities in Canada



Upgrading Challenge

Approach:

- Produce 100kg of catalyst at NREL
- Modify Enerkem's pilot plant to facilitate downstream conversion of methanol to dimethyl ether and subsequently to the high-octane gasoline blendstock
- Demonstrate at least 6 weeks of pilot plant operation, generating ca. 100L of fuel per week
- Analyze fuel properties



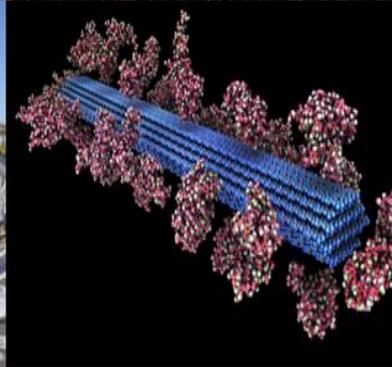
Outcomes:

- Successfully scaled up production of NREL's catalyst from 10g – 100kg in a commercially-relevant extrudate form
- Enerkem's facility modified for production and collection of hydrocarbon stream
- Pilot operations ongoing; approached by auto manufacturer interested in the fuel



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