Production of Renewable Aromatic Chemicals using Virent’s Catalytic BioForming® Process

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Director Feedstock Development
October 19-22, 2010
Today’s Agenda

- Virent Background
- Bio-Based BTX
- Commercialization Status
Virent Energy Systems Overview

The global leader in catalytic biorefinery research, development, and commercialization

Employees

~ 90 Employees
Industry relevant experience

Financial

> $75 MM in Private Funding
> $45 MM in Gov & Industry

Partners & Investors

Cargill
Shell

Infrastructure

> 20 Development Pilot Plants
10,000 gal/yr Process Demo
Virent’s BioForming® Technology

A catalytic route to renewable hydrocarbon fuels and chemicals.

- **Fast and Robust**
  - Inorganic Catalysts
  - Moderate Conditions
  - Industry Proven Scalability

- **Energy Efficient**
  - Exothermic
  - Low Energy Separation
  - Low Carbon Footprint

- **Premium Drop-in Products**
  - Tunable Platform
  - Infrastructure Compatible

- **Feedstock Flexible**
  - Conventional Sugars
  - Non-Food Sugars
Catalytic vs. BioChemical Routes for Fuel and Chemicals Production

- Orders of Magnitude Higher Productivity

Measure of Productivity: Space Time Yield

\[(\text{moles reactant per second per cc of reaction volume})\]

- Tolerant of Variable Feeds
- Produce Range of Molecules
BioFuel Pathways from Biomass

Biomass

- Gasification
  \( \text{CO} + \text{H}_2 \)
- Pyrolysis
  \( \text{CH}_1.4\text{O}_{0.6} \)
- Hydrolysis
  \( \text{CH}_2\text{O} \)

Virent’s BioForming® Process

- Syngas
- Bio-oils
  \( \text{CH}_1.6\text{O}_{0.4} \)
- Sugars
  \( \text{CH}_2\text{O} \)
- Aqueous Phase Reforming
  \( \text{CH}_3\text{O}_{0.5} \)

- Fermentation
  \( \text{CH}_3\text{O}_{0.5} \)
- Catalysis
  \( \text{CH}_3\text{O}_{0.5} \)
- Refining
  \( \text{CH}_2 \)

Fischer-Tropsch

- Diesel
  \( \text{CH}_2 \)
- Jet Fuel

Ethanol

Fermentation

- Methanol
  \( \text{CH}_3\text{O}_{0.5} \)
- Ethanol
  \( \text{CH}_3\text{O}_{0.5} \)

Liquid Fuels

Hydrocarbons

- Ethanol
  \( \text{CH}_3\text{O}_{0.5} \)
- Butanol
- Gasoline, Jet, Diesel, Chemicals, Alcohols, Hydrogen

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Reaction Pathways

Glucose

Xylose

Sucrose

Paraffins

Acid Condensation

Aldol Condensation
Virent’s BioGasoline Product

*Premium product with the same components as petroleum derived gasoline*

- **Unleaded Gasoline**: 115,000 BTUs/Gal
- **Bioforming BioGasoline**: +120,000 BTUs/Gal
- **Ethanol**: 76,000 BTUs/Gal

~ 20 liters of sugar derived gasoline from Virent’s Bioforming process.
Goal: Develop, deploy and commercialize at scale a renewable fuels platform that is superior to conventional fuels

- **Feedstock Logistics**
  - Major Shareholder
  - Participating in feedstock development and commercial deployment

- **Conversion Platform**
  - Platform Research & Development
  - Technology Provider
  - Feedstock R&D
  - Catalyst Development
  - Operations

- **Deployment Opportunity**
  - Development Partner
  - Fuel Qualification
  - Scale-Up Partner
  - Market Channels

- **Customer Acceptance**
  - Support Efforts to Determine BioGasoline’s Suitability in Current & Next Generation Engines
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Benzene, Toluene and Xylenes have a wide range of everyday end use products and are heavily dependent on fossil fuel sources for production.
Typical Aromatics Complex
## Virent BioGasoline Product Comparison

<table>
<thead>
<tr>
<th></th>
<th>Typical Catalytic Reformate (Vol%)</th>
<th>Virent BioReformate (Vol%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffins</td>
<td>22.5</td>
<td>20.6</td>
</tr>
<tr>
<td>Napthenes</td>
<td>0.7</td>
<td>3.9</td>
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<tr>
<td>Aromatics</td>
<td>60.8</td>
<td>64.4</td>
</tr>
<tr>
<td>Overall Totals</td>
<td>84.0</td>
<td>88.9</td>
</tr>
<tr>
<td>Typical RON</td>
<td>~95 - 105</td>
<td>105</td>
</tr>
</tbody>
</table>

*Typical Catalytic Reformate Composition taken from U.S. Patent 4,053,388.*
Typical Aromatics Complex

Virent’s Bioreformate Product Feed Entry

- Hydrogen
- Platforming
- NHT
- Naphtha
- Reformate Splitter
- Sulfolane
- THDA
- Tatoray
- Parex
- Isomar
- Xylenes Splitter
- OX Column
- ortho-Xylene

Products:
- Raffinate
- Benzene Toluene
- Heavy Aromatics
- para-Xylene
- Light Ends
- Heavy Aromatics Col
Fuels and Chemicals

Fuel Prices taken from EIA (Wholesale prices Mar 2010 Monthly Averages)
Chemical Prices taken from ICIS (FOB US Gulf Coast Contract Prices Mar, 2010).
Graph depicts the estimated difference in product value as aromatics over premium gasoline.
Market Opportunity: Renewable PET

How is plantbottle™ PET Manufactured?

- Standard PET
  - Component A 70%
  - Component B 30%

- PlantBottle PET
  - Component A 70%
  - Component B 30%

Plant-Based Material → Ethanol → Component B 30% → PET Resin → Bottle Forming → PET Bottle

http://www.thecoca-colacompany.com/citizenship/plantbottle.html
Virent Enables 100% Renewable PET

- Virent’s BioForming Process enables the production of a 100% renewable PET.
- Bio-reformate and associated xylenes are competitive with petroleum.
- Infrastructure compatibility ensures minimal changes to the existing supply chain.
- Process and product has been demonstrated beyond lab scale.
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Virent Addresses Key Drivers in the Fuels and Chemicals Markets

**Compliance**
Cost effective compliance in global fuels markets with minimal barriers to entry.

**Diversification**
Drop-in hydrocarbons provide diversification in petroleum based industries.

**Financial Returns**
Feedstock and product flexibility enable “no regret” capital investments and superior profit margins.
BioBased Parity with Petroleum

Crude Oil ($/barrel)

BioBased Feedstock Advantage

Petrochemical Feedstock Advantage

Corn ($/bushel)
Sugar Cane ($/tonne)
Biomass ($/dry ton)

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Commercialization and Scale-up

- **Laboratory Scale Development** COMPLETE
  - 0.5 gallon/day
- **Process Demonstration** COMPLETE
  - 10,000 gallon/year capacity
  - 2010 for product volumes and further platform enhancements
- **First Commercial Plant** IN PROCESS
  - Project planning in progress with strategic partners
    - > 20 mm gallon/year capacity
- **Commercial Roll-Out** IN PLANNING
Virent’s Process Demonstration Unit

- Gen 1 sugar-to-gasoline process
- Scale-up of 100X
- 10,000 gallons per year
- Full length reactor and commercial scale catalyst
- Product volumes for registration and fleet testing
- Feedstock handling and purification system flexibility
- Plant start-up in November 2009
- Overall success: on time, under budget, on-spec product
Feedstock Considerations

CURRENT PROCESS

- **COMMODITY SUGARS**
  - Corn Starch
  - Sugar Cane
  - Sugar Beet

- **BIOFORMING**
  - Virent's proprietary process to transform cost-effective sugars into fuels and chemicals

- **HYDROCARBON PRODUCTS**
  - Gasoline
  - Diesel
  - Jet Fuel
  - Chemicals
  - Plastics

IN DEVELOPMENT

- **NON-FOOD SUGARS**
  - Corn Stover
  - Bagasse
  - Switchgrass
  - Miscanthus
  - Wood

- **DECONSTRUCTION TECHNOLOGIES**
  - Liberates sugars from cellulosic biomass cost-effectively

- Evaluating existing pretreatment and hydrolysis technologies for integration with Virent’s process
- Developing proprietary technology for deconstruction of biomass
• Feedstock inputs can vary with market price and to ensure year round operations
• Fast, continuous process lowers capital expenditures
• Low energy requirements minimize operating costs and lifecycle efficiency
• Product mix, and profits, can be optimized based on market demand and pricing
• No barriers to full market penetration
IF YOU CAN GROW IT,
we can convert it into everyday fuels, plastics and chemicals.

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