



Virent is Replacing Crude Oil.

Andrew Held, Director Feedstock Development

Biomass 2011 Conference

DOE Office Of Biomass Program

National Harbor, MD

26 July, 2011

- Company/Technology Background
- Quality Drop-in Products
 - Gasoline, Jet fuel, Diesel and Chemicals
 - Impact on „replacing the whole barrel’
- Feedstock flexibility and development work
 - Biomass feedstocks
 - Impact on „supply the whole market’

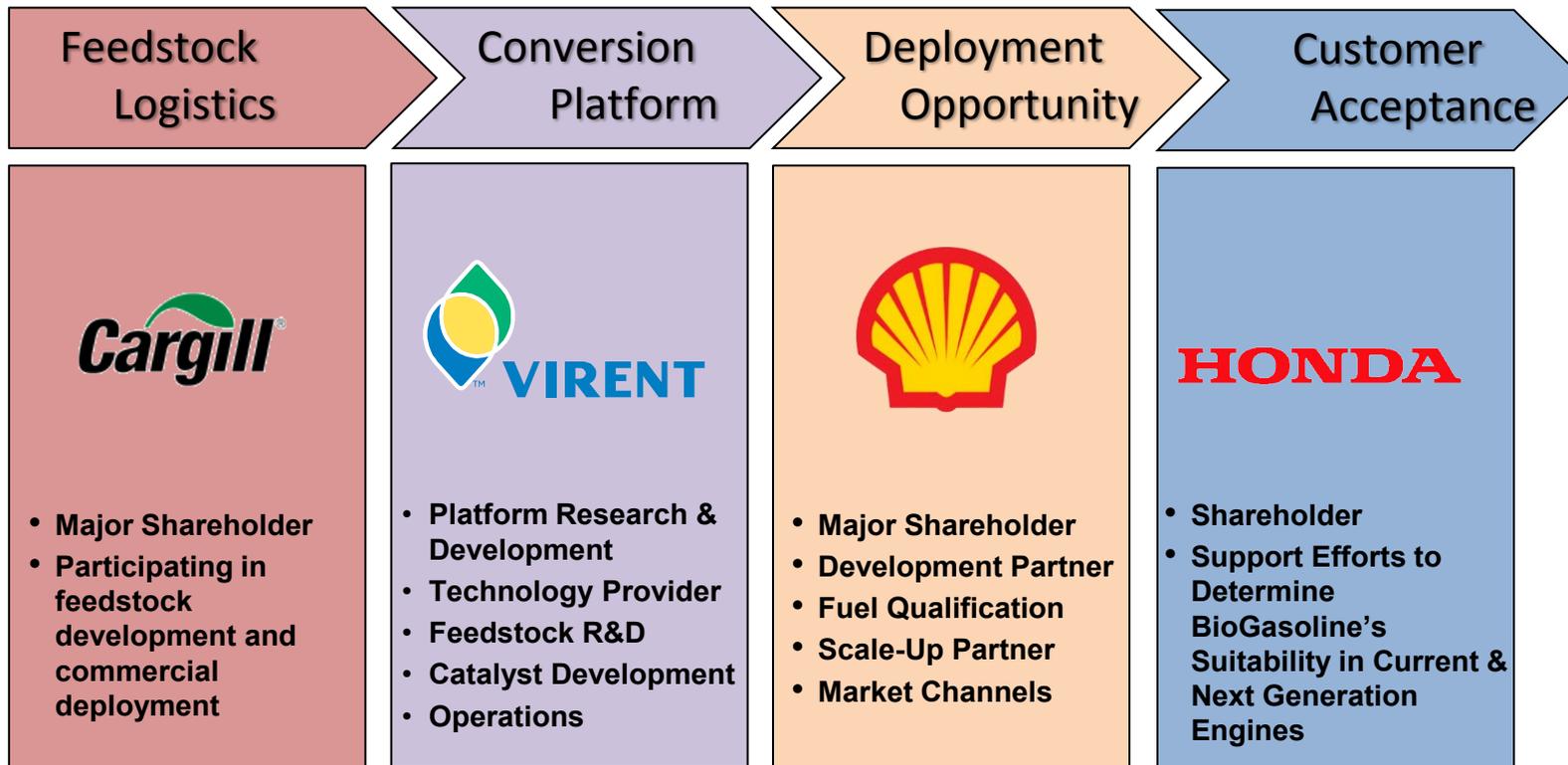
Virent Energy Systems Overview



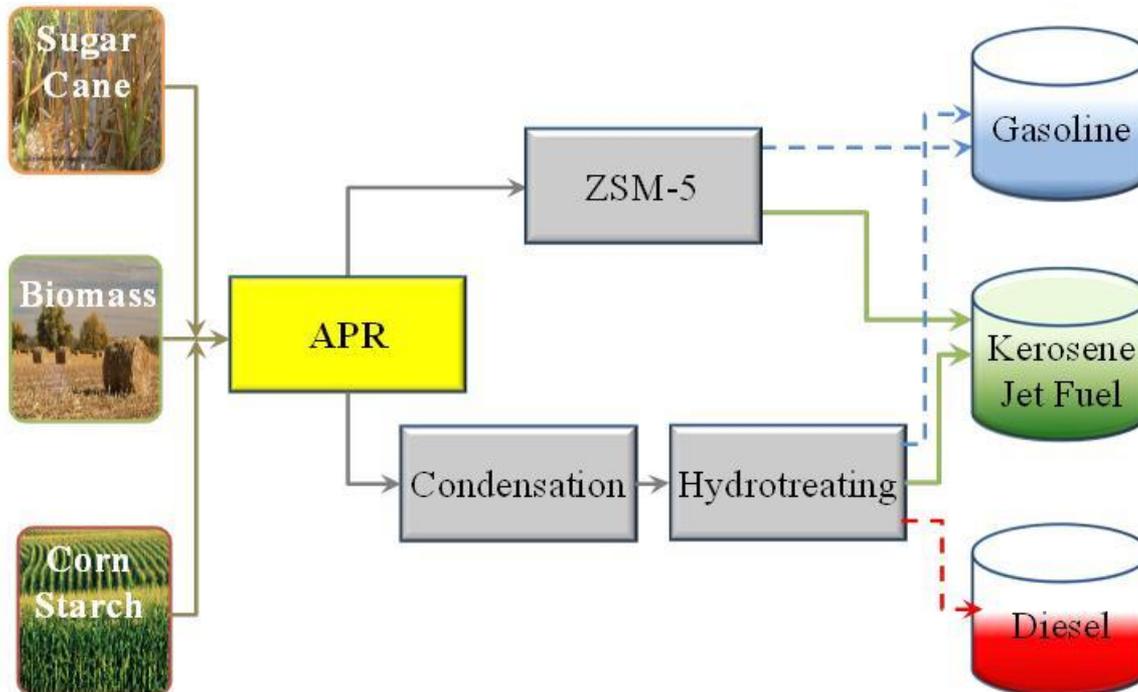
Virent Demonstration Plant

- **Founded in 2002**
- **Based in Madison, WI**
- **> 110 employees**
- **63,000 sq. ft. facility**
- **> 20 pilot plants supporting development and scale-up**
- **10,000 gal/yr process plant supplying product for testing**
- **> \$ 76 MM of equity financing**
- **> \$ 61 MM of development funding from government and industry**

Strategic Investors & Partners



- Virent uses Chemical Catalysis to convert renewable feedstocks to drop-in hydrocarbon fuels and chemicals



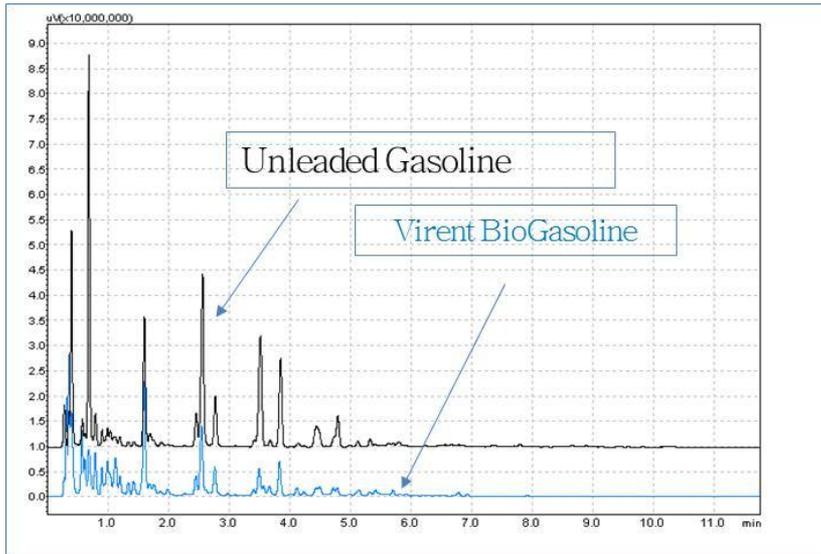
- Quality Products
- Feedstock Flexible
- Proven Deployment
 - High productivity
 - High yields
 - Scale-up
 - Heat integration



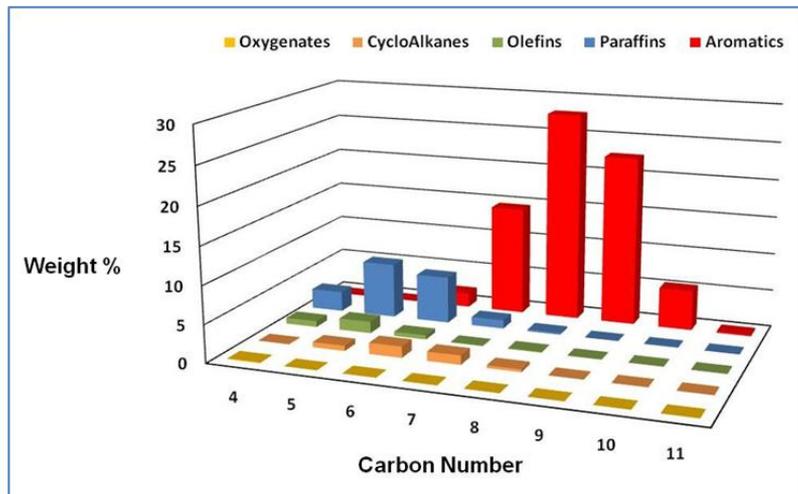
Translates into

- Infrastructure Compatibility
- Energy Security
- Domestic Job Creation

Drop-in Biogasoline

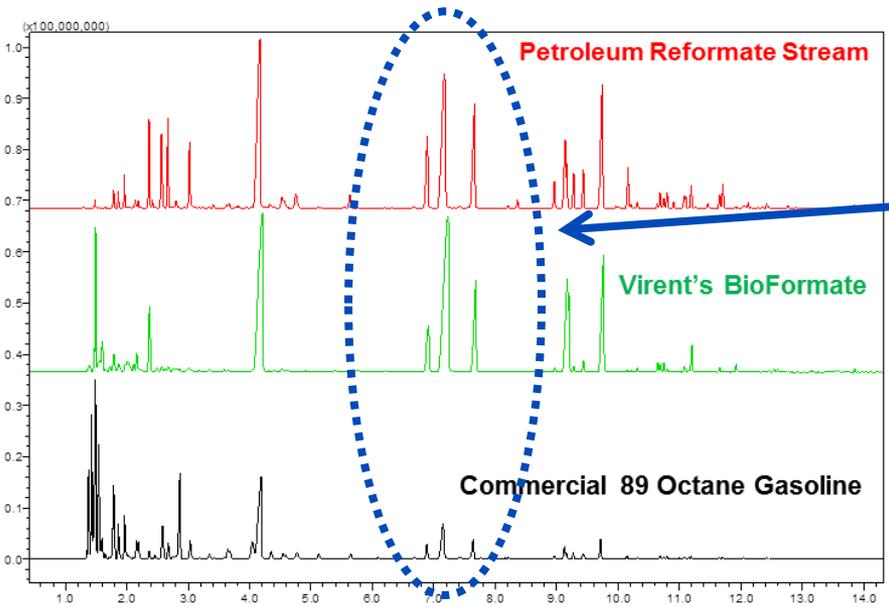


Premium Biogasoline – 120,000 Btu/gal



Virent fuel in Scuderia Ferrari race fuel

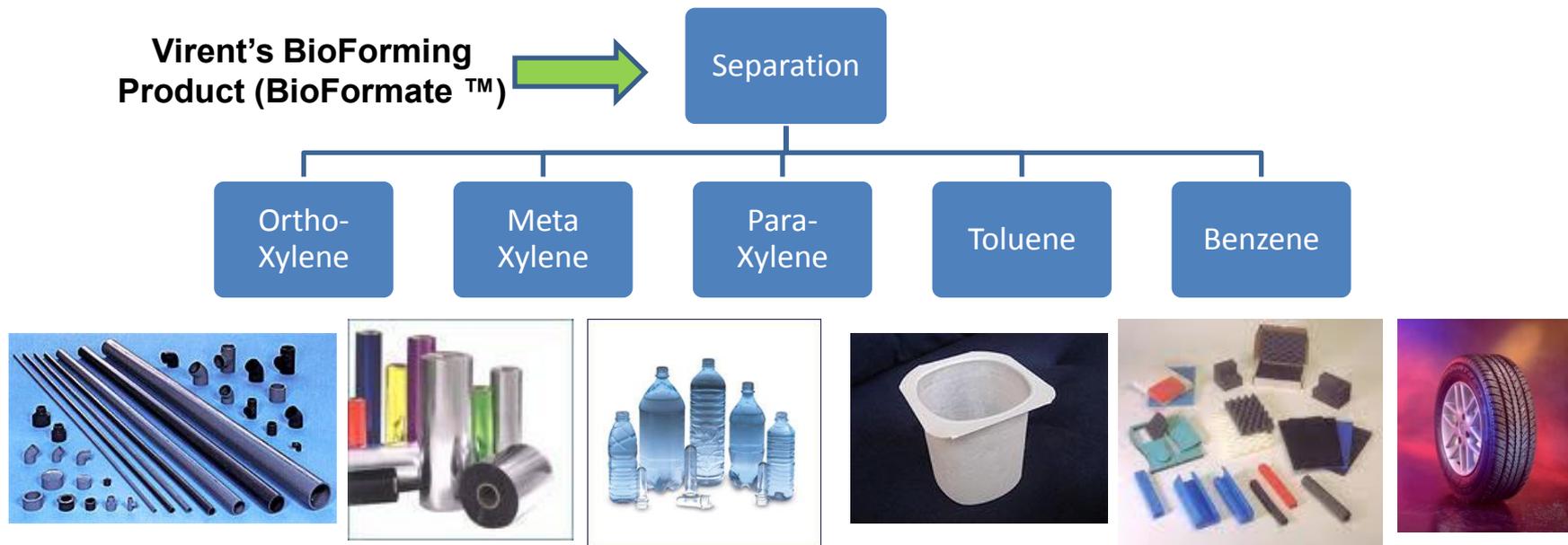
Petroleum Reformate → Renewable BioFormate™



- Rich in C8 Aromatics - Mixed Xylenes
- This BioFormate was made from *cellulosic* material (corn stover)

	Typical Reformate (Vol%)	Virent Bioformate (Vol%)
Paraffins	22.5	20.6
Naphthenes	0.7	3.9
Aromatics	60.8	64.4
Overall Totals	84.0	88.9

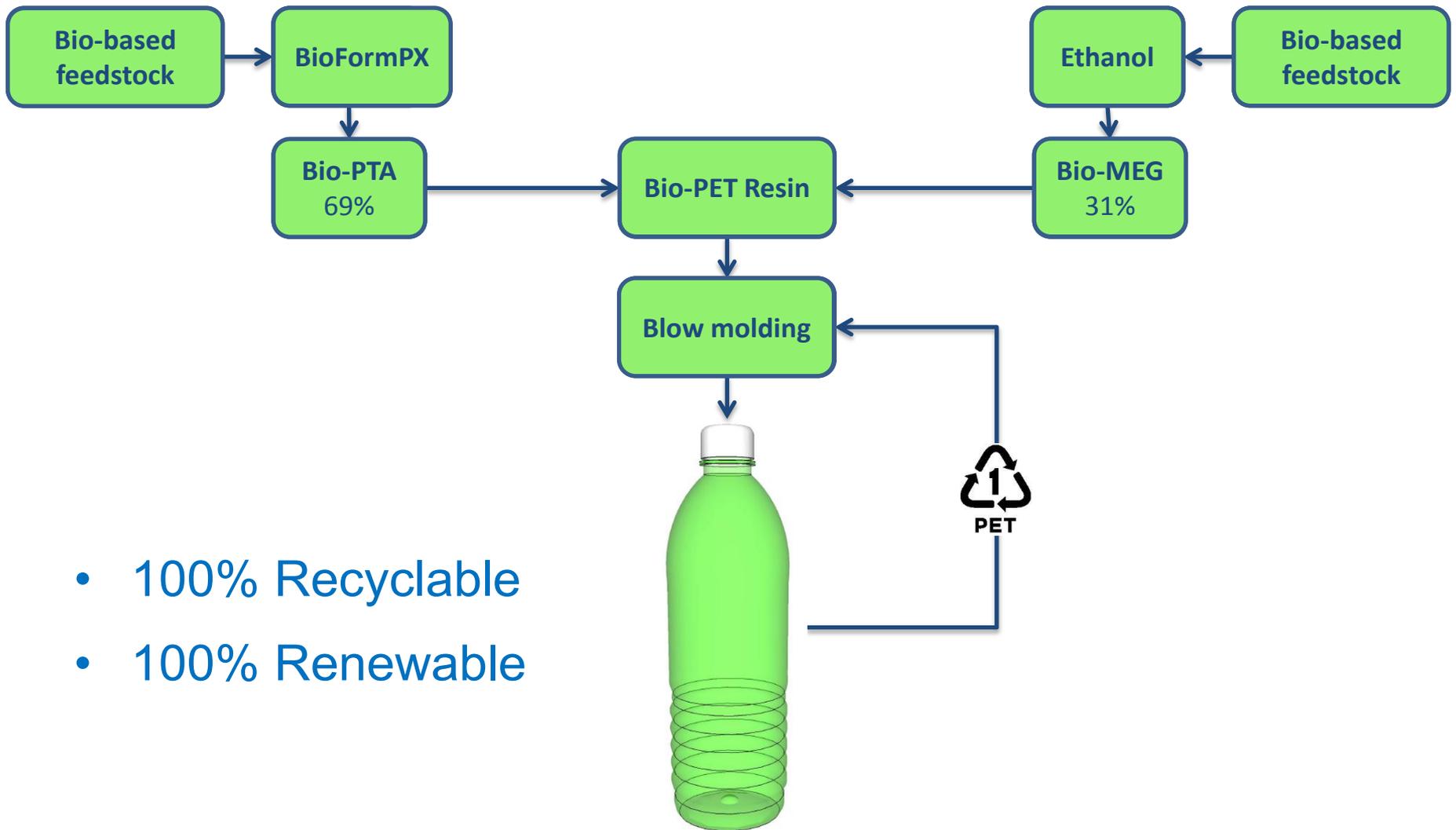
- Leverage biofuels development to supply “like-for-like” chemicals used in everyday materials.
- Benefits of Virent’s approach
 - Infrastructure compatible → Fast to market
 - Enables renewable content in a broad range of products including PET, Polyurethane, and Polycarbonates.



- Virent's bio-based paraxylene - **BioFormPX™** - was separated and purified from BioFormate™ made on Virent's 10,000gal/yr demonstration-scale plant



BioFormPX™ Enables 100% Renewable PET



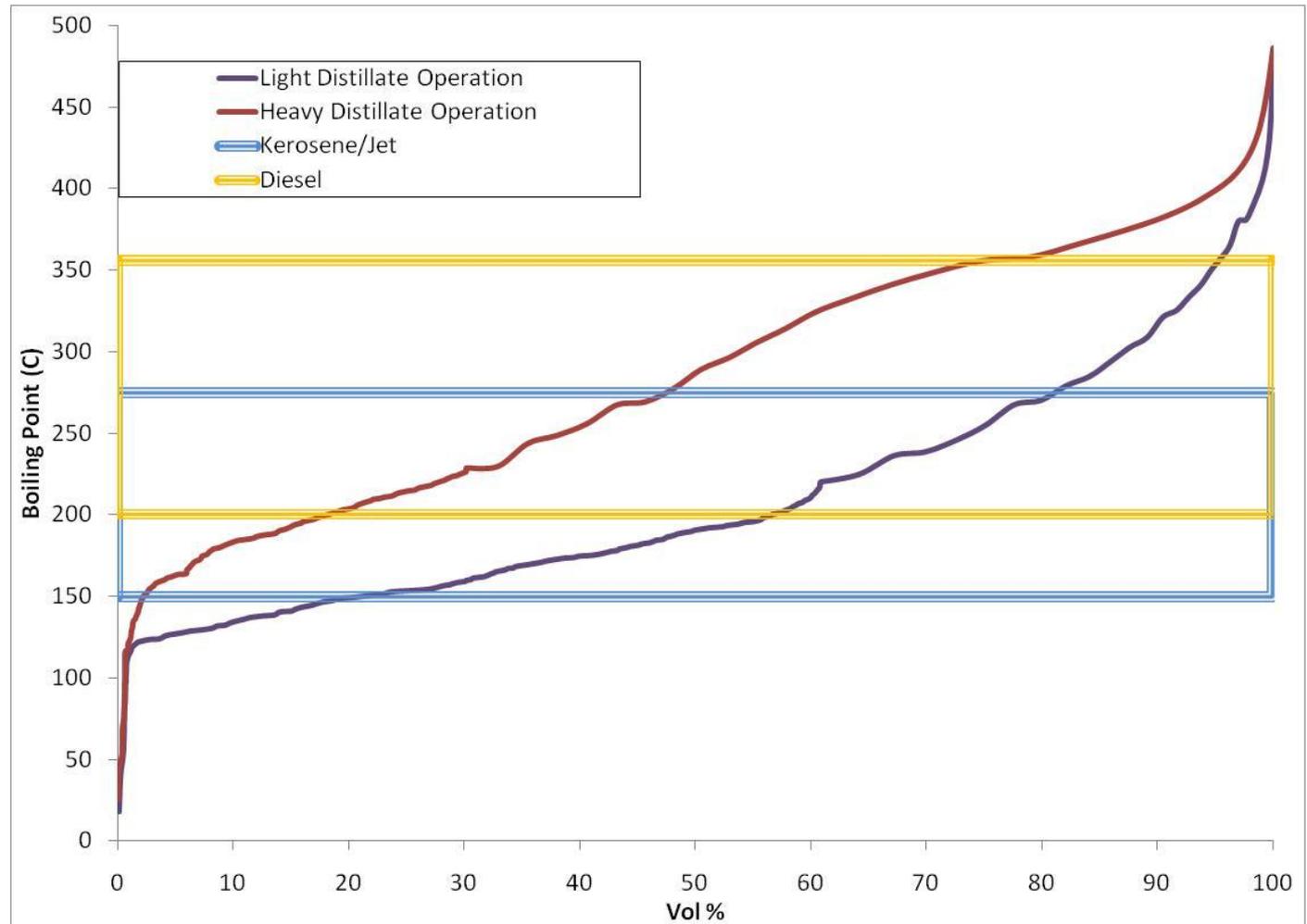
- 100% Recyclable
- 100% Renewable

Adapted from Coca-Cola website graphic
http://www.thecoca-colacompany.com/citizenship/plantbottle_basics.html

Virent's Distillate Products



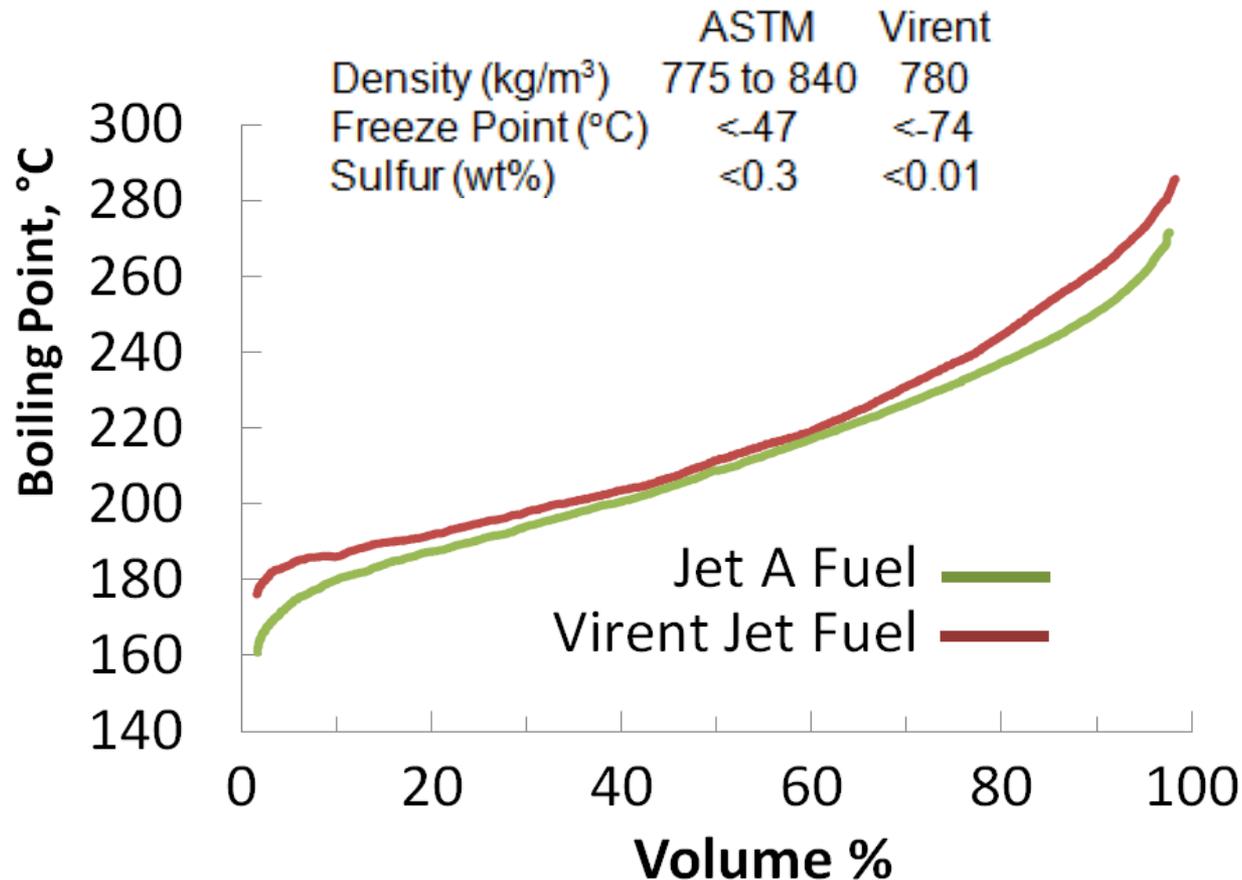
Processes are tunable to produce Distillate products per ASTM.



Virent's Jet Fuel Characteristics – 'RPN'



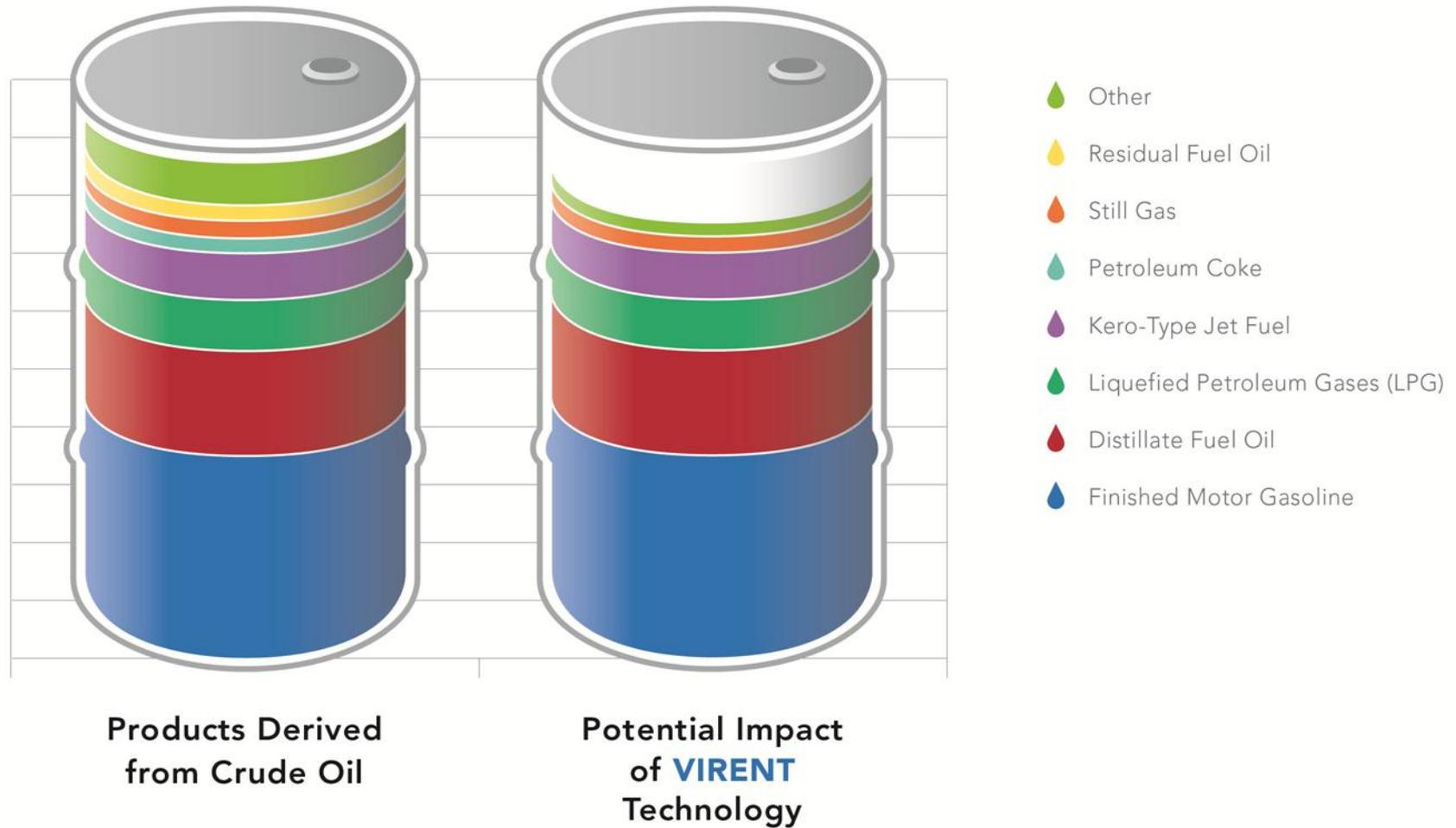
- RPN – Renewable Paraffins and Naphthenes



- Range of molecules makes very good boiling point profile
- Good density and High energy density
- Excellent Freeze point and sulfur content

'Replace the Whole Barrel'

Virent Technology can Address > 90% of the Barrel



Products Derived from Crude Oil

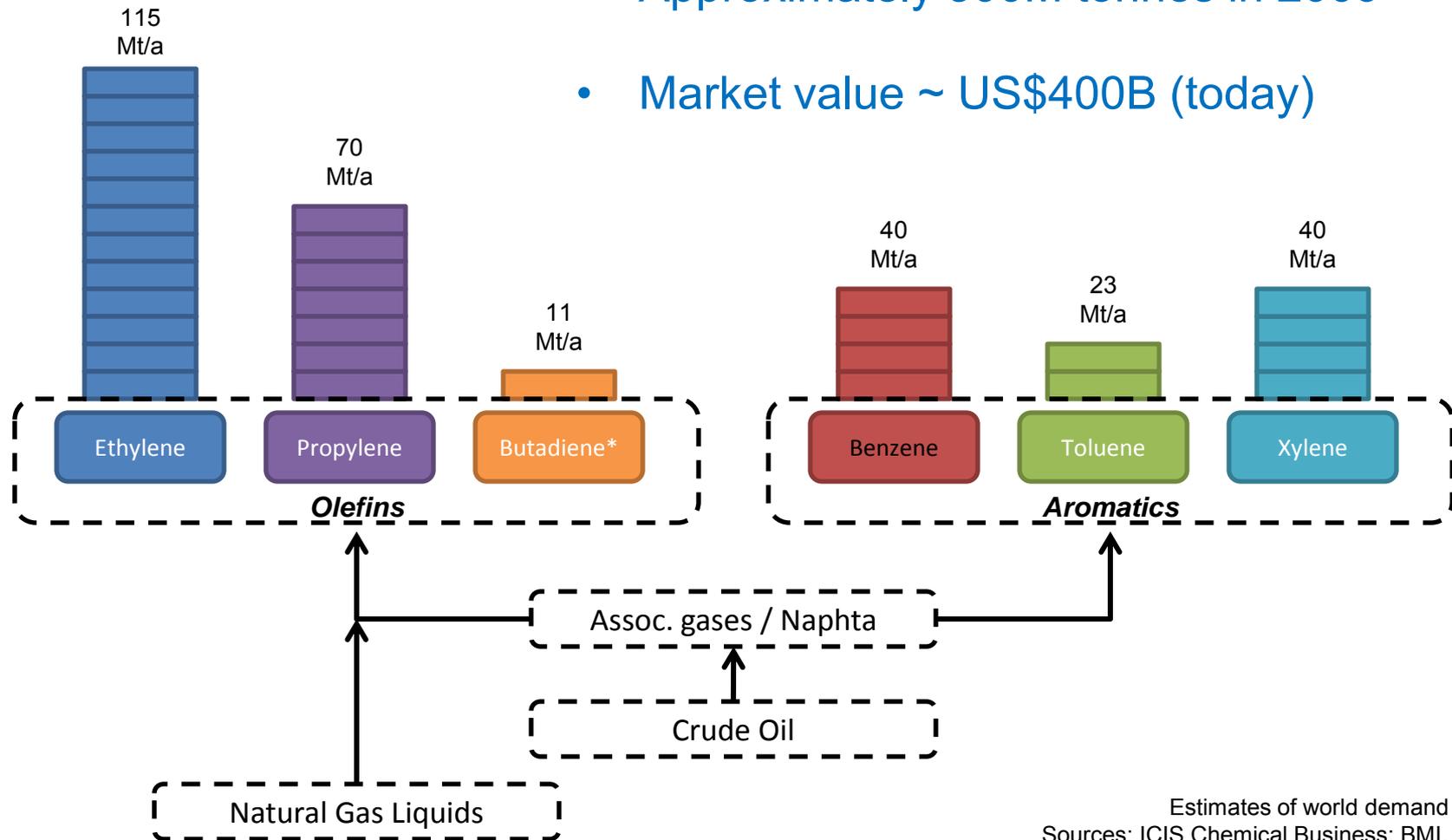
Potential Impact of **VIRENT** Technology

'Supply the Whole Market'

World Petrochemical Volumes



- Approximately 300M tonnes in 2009
- Market value ~ US\$400B (today)

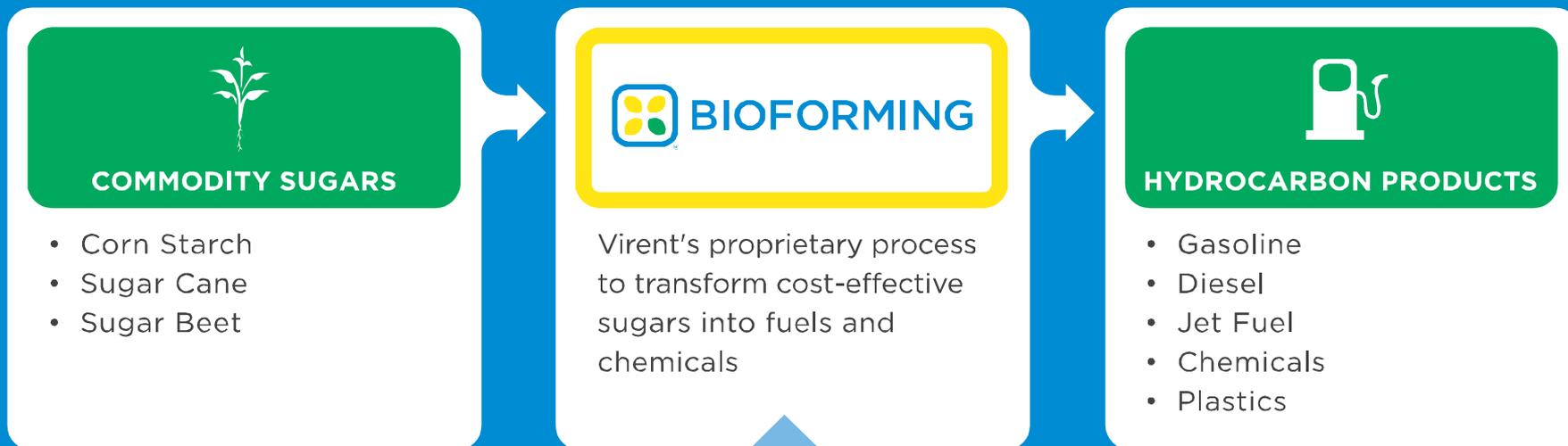


Estimates of world demand , 2009
Sources: ICIS Chemical Business; BMI, CMAI.

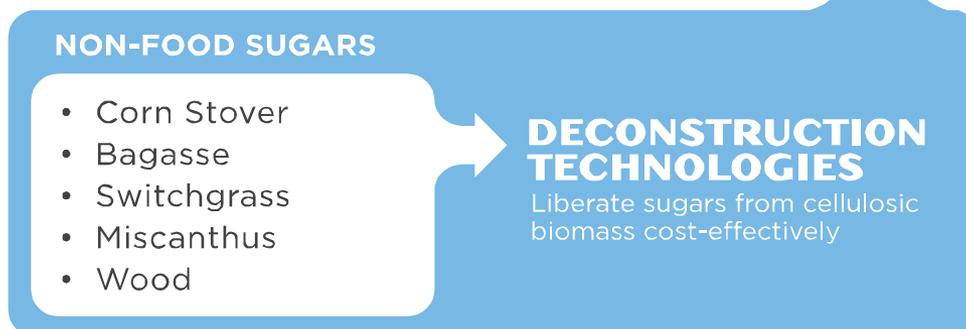
Feedstock Development Work



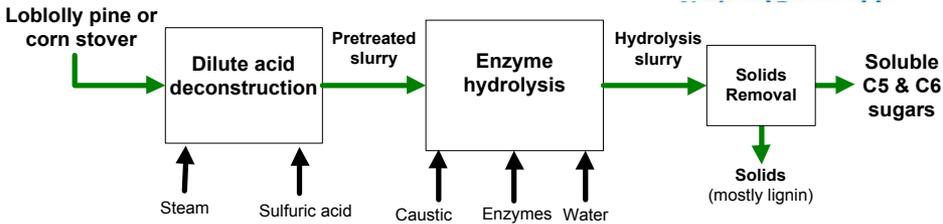
CURRENT PROCESS



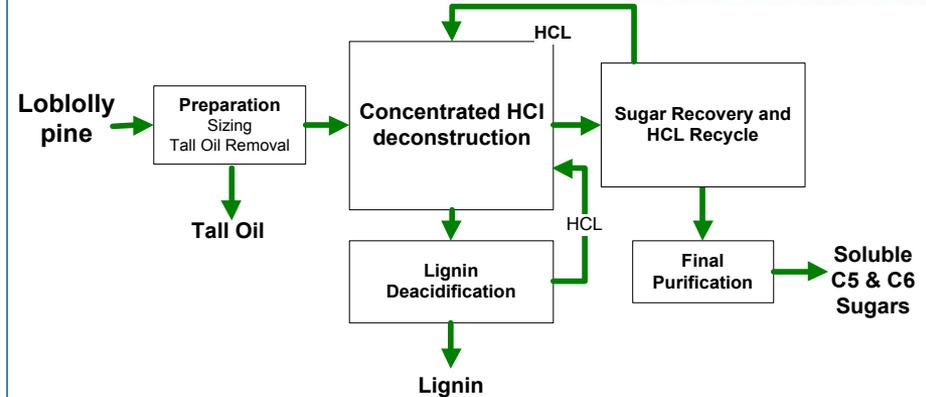
IN DEVELOPMENT



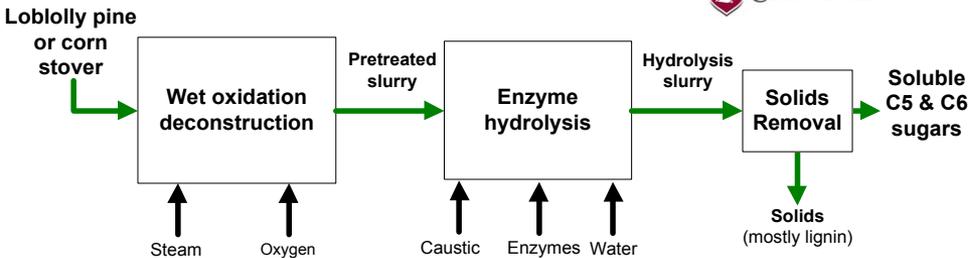
Dilute acid and enzyme hydrolysis



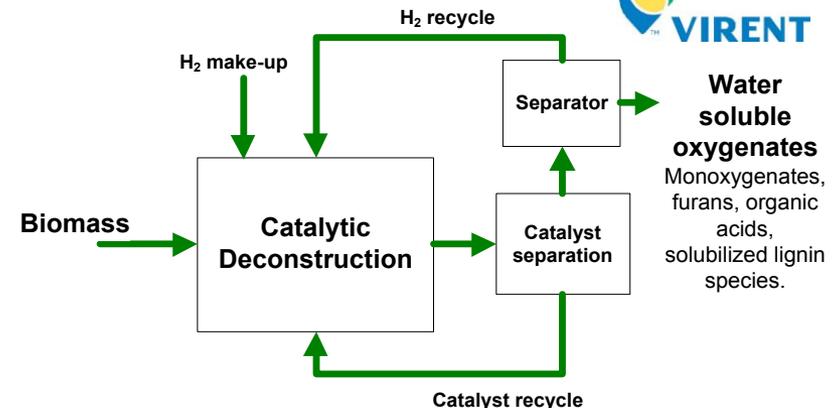
Concentrated Acid Extraction



Wet oxidation and enzyme hydrolysis



Catalytic Biomass Deconstruction

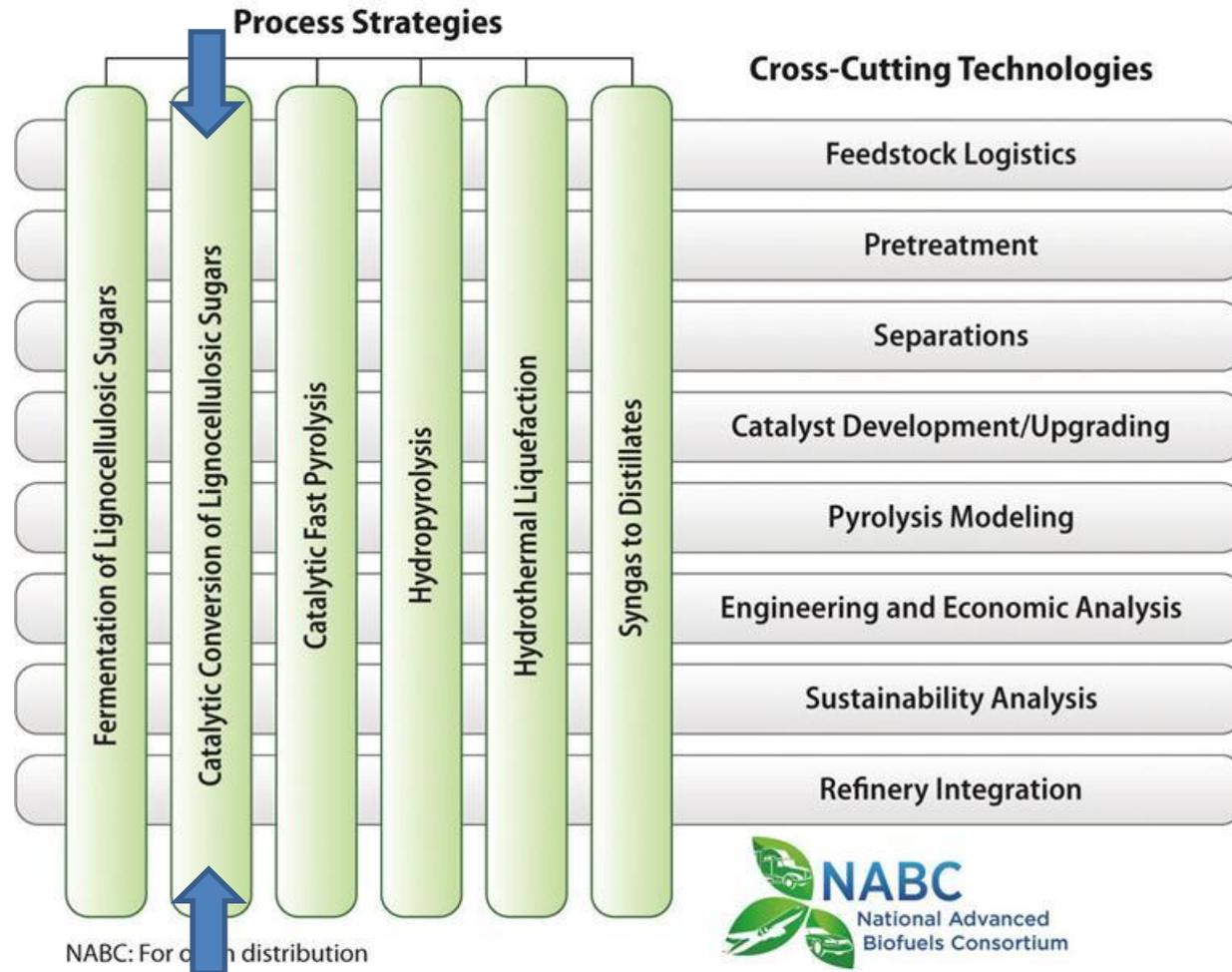


Consortium Leads

National Renewable Energy Laboratory
Pacific Northwest National Laboratory

Consortium Partners

Albemarle Corporation
Amyris Biotechnologies
Argonne National Laboratory
BP Products North America Inc.
Catchlight Energy, LLC
Colorado School of Mines
Iowa State University
Los Alamos National Laboratory
Pall Corporation
RTI International
Tesoro Companies Inc.
University of California, Davis
UOP, LLC
Virent Energy Systems
Washington State University



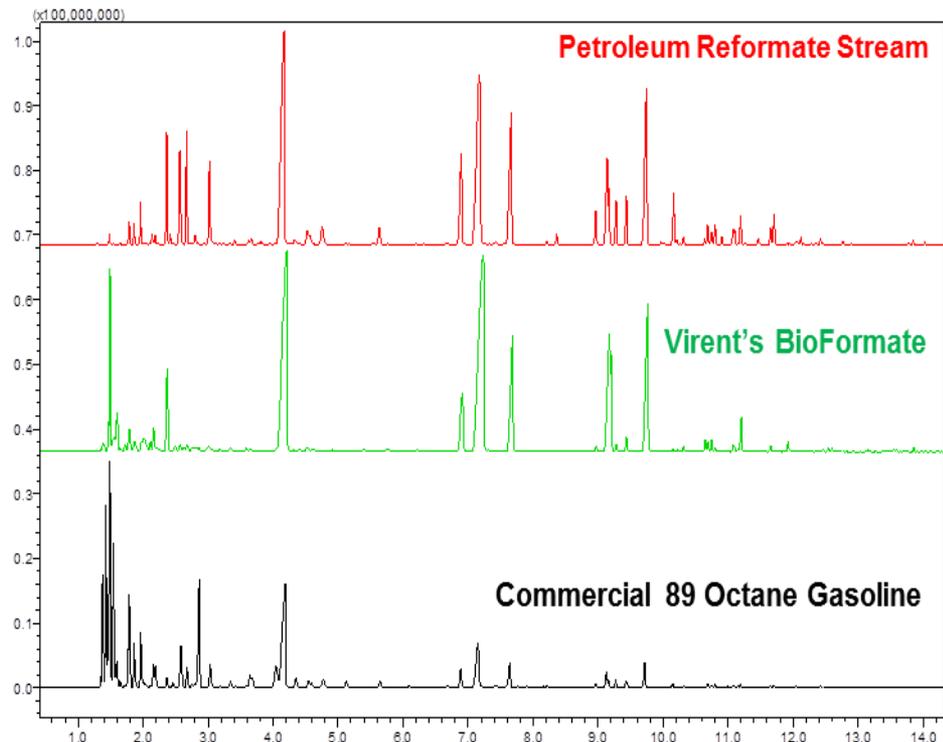
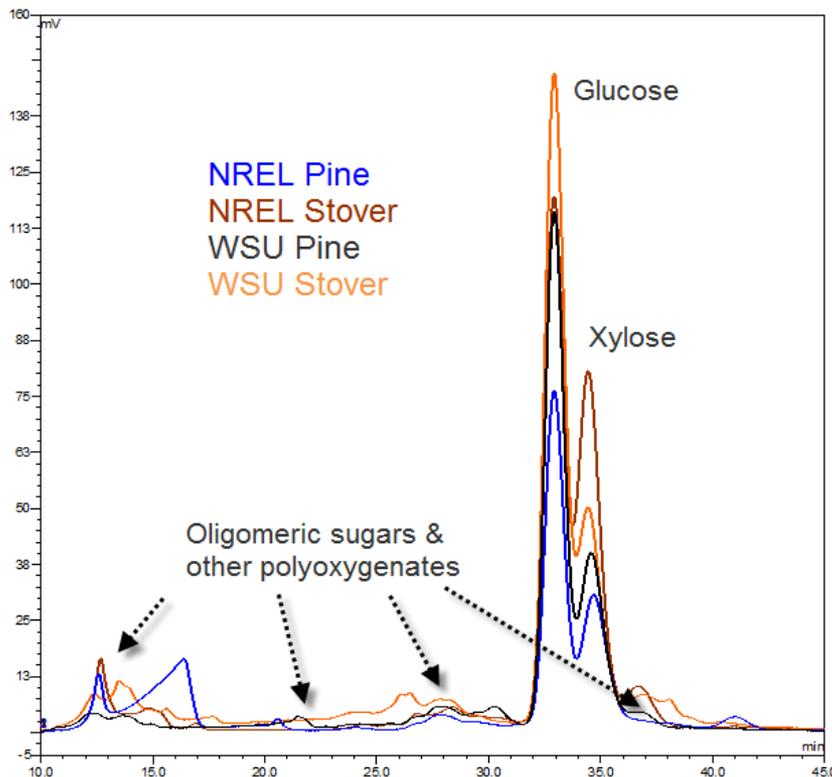
Virent leads the Catalytic Conversion of Lignocellulosic Sugars (CLS) strategy. The underlined parties above are currently collaborating within the CLS strategy.

Recent Developments - Biogasoline



NABC Work

- Stover from ISU, pine residues from Catchlight
- NREL, WSU, and Virent making Hydrolysates
- Virent converted hydrolysates into BioFormate™ gasoline product



- Desirable Feedstock Characteristics
 - 30 to 70 wt% soluble „carbohydrates’
 - Pentoses and hexoses
 - Mono- & oligosaccharides (DP₁ to DP₁₀₊)
 - Significant wt% Furans, organic acids
 - Primary Impurity concerns
 - Amino acids (nitrogen)*
 - Low in ash (e.g., sulfur)*
 - Biochemical & Thermochemical process synergies
 - Decolorizing is less important; hydrotreating is possible

*E.g., Deactivation of metal catalysts in liquid phase organic reactions; Besson and Gallezot, *Catalysis Today*, 81 (2003) 547-550

Cellulosic biomass to gasoline, 6/2/2011



Virent's Project Collaborators

IOWA STATE UNIVERSITY



chemicalweek

Virent Unveils Biobased P-Xylene Process

2:52 PM MDT | June 6, 2011 | Rebecca Coons



Coca-Cola is working to increase the renewable content of its packaging.

Virent (Madison, WI), a catalytic chemistry firm, says it has successfully produced *para*-xylene (*p*-xylene) from plant-based sugars. The *p*-xylene, which Virent has tradenamed BioFormPX, is identical to *p*-xylene produced via petroleum-based processes and can be used as a drop-in replacement in the value chain, says Kieran Furlong, Virent's commercial manager/chemicals.

The breakthrough will allow polyethylene terephthalate (PET) manufacturers to produce the commodity resin entirely from renewable resources. Coca-Cola has been selling its



Virent's plant-based para-xylene



DOE Award

- Announced June 10, 2011
- Cellulosic sugars to jet fuel
- \$13.4 MM Grant
- 3 year project



Project Partners



➔ Jet fuel production



➔ Corn stover processing



➔ Modeling

Recent Virent Press Releases

- Biogasoline - [Virent Makes Biogasoline from Cellulosic Biomass](#)
- Chemicals - [Virent Makes Renewable Paraxylene](#)
- Jet Fuel - [Virent DOE Jet Fuel Award Announcement](#)

Other sources

- Biogasoline announcement from [NABC public website](#)
- Chemicals – [Biofuels Digest Article](#)
- Jet Fuel – DOE site -

[http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=17442.](http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=17442)

IF YOU CAN GROW IT,
we can convert it into everyday fuels, plastics and chemicals.



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Director Feedstock Development
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Virent is replacing crude oil. Visit our [website](#) to learn how.