Bio-Based Paraxylene for PET

Bringing BioBased Paraxylene Through the PET Supply Chain with Key Partnerships

Kieran Furlong, Director Chemicals Business Development

4th Annual Infocast Biobased Chemicals Summit, January 29th 2013

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Green Chemicals

BIO-PX Holds the Key

100% renewable PET bottles will need this component
### Beyond Flat

Volume performance of beverages by brand in 2011

<table>
<thead>
<tr>
<th>Brand</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dasani</td>
<td>11%</td>
</tr>
<tr>
<td>Arizona</td>
<td>9.3</td>
</tr>
<tr>
<td>Gatorade</td>
<td>8.0</td>
</tr>
<tr>
<td>Aquafina</td>
<td>2.1</td>
</tr>
<tr>
<td>Dr Pepper</td>
<td>0.4</td>
</tr>
<tr>
<td>Sprite</td>
<td>-0.5%</td>
</tr>
<tr>
<td>Mountain Dew</td>
<td>-1.0</td>
</tr>
<tr>
<td>Coke</td>
<td>-1.5</td>
</tr>
<tr>
<td>Nestle Pure Life</td>
<td>-1.7</td>
</tr>
<tr>
<td>Pepsi</td>
<td>-5.5</td>
</tr>
</tbody>
</table>

Note: Includes soda and noncarbonated drinks.
Source: Beverage Digest

Wall Street Journal, May 15th 2012
Virent at a Glance

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

**Employees**

120 Employees

**Technology**

Converting plant-based feedstocks to fuels and chemicals

**Infrastructure**

25x Development Pilot Plants
1x 10,000 gal/yr Demo Plant

**Partners & Investors**

Cargill
The Coca-Cola Company
Honda

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Global Petrochemical Market

- Approximately 330M tonnes in 2011
- Market value ~ US$440B
- BTX Market value ~ US$130B

Estimates of world demand, 2011
Sources: IHS Chemical, ICIS.

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Global Petrochemical Market

Same polymers, same performance, same equipment

Polystyrene  Nylon  Polycarbonate  Phenolics  Polyurethane  Polyester

Benzene  Toluene  Xylene

Aromatics
BTX Aromatic Product Tree

- **Ortho-Xylene**
  - Plasticizers
  - Polyethylene Naphthalate (PEN)

- **Meta-Xylene**
  - Purified Isophthalic Acid (PIA)
  - Polyethylene Terephthalate (PET)

- **Para-Xylene**
  - Purified Terephthalic Acid (PTA)
  - Polyethylene Terephthalaes (PET)

- **Toluene**
  - Toluene Diisocyanate (TDI)
  - Polyurethane Foams
  - TNT

- **Benzene**
  - Polycarbonates
  - Phenolic Resins
  - Nylon 6
  - Polystyrenes

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PX World Market

<table>
<thead>
<tr>
<th>Year</th>
<th>World Consumption (million metric tons)</th>
<th>World Market Size (2010 USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>30Mt</td>
<td>$39B</td>
</tr>
<tr>
<td>2020</td>
<td>57Mt</td>
<td>$116B</td>
</tr>
</tbody>
</table>

Sources: PCI; EIA.

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Global PET Usage and Growth

- Primary use of PX is conversion to PTA and then PET
- Global PET is projected to double from 2010 to 2020.
- Fiber is the main use of PET
- Majority of PET and PX production is in the Asia/Pacific region

Data compiled from PCI.

Data compiled from CMAI World Petrochemical Conference - 2011.
Global Benzene Uses and Growth 2011

- Benzene
  - 41.5 M Metric Tons
  - 3.3%/yr

- Ethylbenzene
  - 51%
  - 3.2%/yr

- Cumene
  - 20%
  - 3.75%/yr

- Cylohexane
  - 10%
  - 2.1%/yr

- Nitrobenzene
  - 7%
  - 4.5%/yr

- Alkyl Benzene
  - 3%
  - 2%/yr

- Polystyrene

- Polycarbonates

- Phenolic Resins

- Nylon 6

- Polyurethanes

- LAB/LAS

Major Benzene derivatives

Data adapted from IHS World Petrochemical Conference – 2012 (Moorhouse). Growth Rates are from 2011 to 2016.
Benzene Global Supply and Market Considerations

- Shifting towards lighter feedstocks in crackers will produce less benzene.
- Increased ethanol blending may reduce need for aromatic octane boosters in gasoline.
- Decrease in US gasoline demand lowers need for reformate.
- MSAT 2 decreases amount of benzene that can be present in gasoline.

Sources of Benzene Production – 2011 (IHS)

- Pygas 39%
- Reformate 36%
- Coke 16%
- Oven 5%
- HDA, 4%
- PX Co-Product

Benzene (t) produced per unit of ethylene (t)

- Lighter Feedstocks
- Ethane
- Propane
- Butane
- Light Naphtha
- Heavy Naphtha
- Gasoil

Data adapted from IHS World Petrochemical Conference – 2012 (Moorhouse).
Why are customers interested?

- Diversifying supply & tackling volatility
- Consumer interest and demands
- Supply as co-product diminishing
- New PTA capacity not matched by PX
BioForming® Technology
Virent’s BioForming® Technology

Leading 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
- Fuels and Chemicals

Feedstock Flexible
- Conventional Sugars
- Non-Food Sugars

>50 issued/allowed patents
>150 pending patent applications

Virent’s “Eagle” Demonstration Plant- Madison, WI
The BioForming® Concept

*Biobased feedstocks to direct replacement products*

- APR prepares biomass derived feedstocks for optimal conversion into hydrocarbons
- Feedstocks to APR include any water soluble carbohydrate
- Option for natural gas co-processing (HDO) can improve yields and economics
- Demonstrated process yields are > 80% of theoretical
The BioForming® Concept

*Biobased feedstocks to direct replacement products*

- **Biomass**
- **Sugar Cane**
- **Corn**

**APR/HDO**

- **Intermediates**
  - Alcohols
  - Ketones
  - Aldehydes
  - Furans
  - Polyols

**Modified ZSM-5**

**Condensation + Hydrotreating**

Potential products for use as solvents, monomers, etc
Partnership
Supply chain innovation

- Opportunity to **vertically integrate** all the way back to raw feedstock.
- Reduce exposure to crude oil volatility, increase security of supply.
- Address sustainability requirements of the consumer and regulator.
- No impact to recycling infrastructure.
- Three integration points enable flexible entry to existing supply chain
Coca-Cola & Virent Partnership

- 2011 - Virent and The Coca-Cola Company sign agreements to develop and supply PX for 100% renewable, recyclable PlantBottle™

- Multi-million dollar, multi-year agreements with Virent
  - Joint Development Agreement
  - Supply Agreement

- Supporting Virent’s plans for first chemicals plant
100% Bio-based Paraxylene

Virent Inc.
3571 Anderson St
Madison, WI 53704
U.S.A

Date: 1/5/2012

CERTIFICATE OF ANALYSIS

<table>
<thead>
<tr>
<th>Product name</th>
<th>BioFormPX</th>
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<tbody>
<tr>
<td>Product code</td>
<td>CO101D</td>
</tr>
<tr>
<td>Product description</td>
<td>Bio-based paraxylene</td>
</tr>
</tbody>
</table>

| Lot number: | CO101D-46880-00 |

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>Provisional Specification</th>
<th>unit</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>PX purity, minimum</td>
<td>modified ASTM D3798</td>
<td>( \geq 99.7 ) wt%</td>
<td></td>
<td>99.98</td>
</tr>
<tr>
<td>Toluene, maximum</td>
<td>modified ASTM D3798</td>
<td>( \leq 0.1 ) wt%</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>o-Xylene, maximum</td>
<td>modified ASTM D3798</td>
<td>( \leq 0.1 ) wt%</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>m-Xylene, maximum</td>
<td>modified ASTM D3798</td>
<td>( \leq 0.1 ) wt%</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Ethylbenzene, maximum</td>
<td>modified ASTM D3798</td>
<td>( \leq 0.2 ) wt%</td>
<td></td>
<td>0.01</td>
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<tr>
<td>Nonaromatic hydrocarbons, maximum</td>
<td>modified ASTM D3798</td>
<td>( \leq 0.2 ) wt%</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Appearance</td>
<td>ASTM D2090; Visual</td>
<td>NA</td>
<td></td>
<td>Pass</td>
</tr>
<tr>
<td>Color, maximum</td>
<td>ASTM D1209; ASTM D 5386</td>
<td>10</td>
<td>NA</td>
<td>Pass</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Modified (modifications available upon request)

\(^{(2)}\) Clear, no sediment when between 18\(^\circ\)C and 25.6\(^\circ\)C (65 to 78\(^\circ\)F)

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Virent's plant-based paraxylene
Summary

- Growing demand for bio-based aromatics due to
  - Consumer demands and desire for differentiation
  - Shifts in petrochemical supply dynamics and fears
  - Tackling volatility with a portfolio approach

- Partnership value to start-ups include
  - Economic de-risking of new projects
  - Funding
  - Leverage in existing supply chain
  - Defining which criteria are important (e.g. sustainability)
  - Co-location (with manufacturing partners)
  - Technology and product validation
Thank you.

Virent converts plant-based sugars into 100% renewable chemicals and fuels. Our bio-based products are identical to those produced from petroleum — direct replacements that utilize today’s manufacturing, storage and supply chain infrastructure. If you are interested in strategic partnering opportunities please contact:

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kieran_furlong@virent.com