The twelve sugar-based building blocks are 1,4-diacids (succinic, fumaric and malic), 2,5-furan dicaarboxylic acid, 3-hydroxy propionic acid, aspartic acid, gluca ric acid, glutamic acid, itaconic acid, levulinic acid, 3-hydroxybutyrolactone, glycerol, sorbitol, and xylitol/arabitol.
Purpose of Pairing: New Materials

• Polymer systems (bioplastics) with high performance
  – tensile strength, impact resistance/ductility, heat deflection, optical clarity in line with the best fossil-carbon incumbents
  – simplest production routes with best economics

• Small molecules
  – dozens of renewable alternatives compete
  – not a ‘low hanging fruit’
## Recognizing the Patterns of Pairing

*Credit to Dr. Sergey Selisonov*

<table>
<thead>
<tr>
<th>Pairs</th>
<th>Base Polymer Properties</th>
<th>Complexity **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levulinate (C5) + Glycerol (C3)*</td>
<td>Rubber, Tg ~10°C</td>
<td>4</td>
</tr>
<tr>
<td>Levulinate (C5) + Erythritol (C4)</td>
<td>Rubber, Tg various</td>
<td>4</td>
</tr>
<tr>
<td>Levulinate (C5) + Sorbitol (C6)</td>
<td>Bioplastic with moderate Tg</td>
<td>5</td>
</tr>
</tbody>
</table>
| Levulinate (C5) + Xylitol (C5)       | Bioplastic, Tg 116°C  
High tensile strength, impact resistant/ductile, optically clear/colorless | 2             |

* 2005  ** number of building blocks for synthesis of useful polymer
PXLK Bioplastic – the Pinnacle of Levulinic Ketals

Credit to Dr. Sergey Selifonov

PXLK

C5 + C5

Poly (Xylitol, 1,4-anhydro-, Levulinate Ketal)
Economics of Every Step is the Key

Bridging the GAP

Growing Value from Non-Food Agricultural Feedstocks
GRASPLEX : One-of-a-Kind Technology

Mastering the Entire Value Chain

Local Distributed Manufacturing
Biomass Hydrolysis
Pentoses (C5 sugars)
Industrial Chemicals
Performance Bioplastics

Doubling the economic output of leading crop systems via distributed conversion of excess non-food plant biomass into valuable food, feed and chemical products

- Worldwide deployment of a thermochemical process system with low-CapEx units and versatility for agricultural feedstocks
- Staggered capital commitment for building capacity to match market demand
Why Waste Renewable “Carbon Ore”?  
A Trillion-Dollar Loss – Annually…

>23% of total carbon is released annually by agricultural field burning

Co-generation plants: a small biomass fraction for energy

A composite image of annual agricultural fires (an overlay of seasonal fire data)

http://www.mississippi-crops.com/2013/09/03/burning-stalks-what-does-it-really-cost/
Unmet Needs in Biomass-based Agritech

Smaller ● Simpler Design ● Low in Cost

Prohibitive CapEx for cellulosic conversions demands new paradigms

http://blog.abengoa.com/blog/2014/02/12/cellulosic-ethanol-takes-off-faces-challenges/
Lessons from Henry Ford

“I will build a car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one — and enjoy with his family the blessing of hours of pleasure in God's great open spaces.”

-- Henry Ford

We will build a PHOENIX for the great multitude...
...Small enough...
...Simplest design...
...So low in price...
Our Biomass Separation Strategy Is Optimized for Value Generation

PHOENIX

PRIMARY HYDROLYZATE (SOLUBLE MATTER)

Hemicellulose
(polymers of C5 sugars: xylose, arabinose, minor C6 sugar amounts)

C5
Pentoses: Most Valuable

C6
Cellulose
(polymer of glucose (beta 1,4- glycosides))

Lignin
(aromatic “insoluble” thermoset polymer)

Minerals
& other minor solubles

INSOLUBLE RESIDUAL SOLIDS (ENERGY FOR STEAM & HEAT)

2-3x Reduction of Pentose Cost
Proprietary Unit and Process: PHOENIX

Primary Hydrolysis Operation and Extraction of Nutrient Inorganics and Xylose

C5-Selective Continuous Low CapEx

- Overcomes the main challenge of handling biomass solids
- Capacity expansion by adding unit clones of optimal size (no scale-up risk)
- Pre-fab compact equipment parts; mass produced, no exotic components or high end alloys
- Cellulose and lignin not separated
- Versatility for biomass types; tolerant to contamination by soil
- Avoids use of undesirables: strong mineral acids, alkali, SO₂, ammonia, oxidants, organic solvents
- Recovered minerals reused as fertilizers for crop production
- Small radius for biomass collection, <10 miles

Production capacity at ~4,000 T/Y (net pentoses as primary C5 hydrolyzate)

- Biomass input at ~20,000 T/Y per unit
- Liquid transportable product (“syrup”)
- Off-spec biomass inputs still give syrups usable for making industrial chemicals
Staggered CapEx deployment to balance supply/demand ramp-up

Dramatic reduction of biomass transportation costs
(<10 miles collection radius)
Staged C5 Product/Market development

Output of PHOENIX will be further processed to valuable products to address (unmet) needs in large world markets.

**Industrials Chemicals**

**BIOPLASTIC**

**PXLK & Gen2**

**Food**
- C5-formulated sucrose (create brand)

**Industrials Chemicals**

**Refined Pentoses**

**Furfural**
- Drop-in chemical

Pentosane Hydrolyzate (C5)
Unmet Needs in Food

Reduction and delay of glycemic response to sucrose to fight diabetes pandemic worldwide

Runaway glycemic response to sucrose (postprandial hyperglycemia, blood glucose spike over time)

Hypoglycemic “aftershock” (hunger period)

Pentoses (xylose, L-arabinose) are safe mild inhibitors of human intestinal sucrase!

Changes in glucose during moderated response (desired)

Sucrose-containing products co-formulated with ~5 % pentose have a reduced postprandial response in humans

Solution: co-formulate sucrose & sucrose-based products with pentoses. Hemicellulose of biomass is the only viable source of suitable food-grade pentoses

C5 for Curbing Diabetes/Obesity Pandemic

>$500 Billion Health Expenditures

>400 Million Cases

*(many more people at risk)*

Health expenditure (USD) due to diabetes (20-79 years), 2013
**Postprandial Effect of L-Arabinose**

### 75g Sucrose + 3g L-Arabinose

<table>
<thead>
<tr>
<th>Glucose Peak</th>
<th>Insulin Peak</th>
<th>C-peptide Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓ 11%</td>
<td>↓ 33%</td>
<td>↓ 23%</td>
</tr>
<tr>
<td>Lower</td>
<td>Lower or Delayed</td>
<td>Lower or Delayed</td>
</tr>
</tbody>
</table>

No effects on triacylglycerol, gastrointestinal symptoms, appetite ratings, or energy intake were observed.

### In Vitro: 0.84, 1.4, and 2.8 mmol L-arabinose/L resulted in 25%, 29%, and 38% inhibition of intestinal sucrase activity, respectively.

*Am J Clin Nutrition, August 2011 vol. 94 no. 2 472-478*
Xylose Effect on Serum Glucose and Insulin

50 g Sucrose + 5g Xylose

Area Under Curve – Glucose (AUCg)

<table>
<thead>
<tr>
<th>Time</th>
<th>AUCg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15min</td>
<td>↓47%</td>
</tr>
<tr>
<td>0-30min</td>
<td>↓39%</td>
</tr>
<tr>
<td>0-45min</td>
<td>↓35%</td>
</tr>
<tr>
<td>0-60min</td>
<td>↓32%</td>
</tr>
<tr>
<td>0-90min</td>
<td>↓26%</td>
</tr>
</tbody>
</table>

Area Under Curve – Insulin (AUCi)

<table>
<thead>
<tr>
<th>Time</th>
<th>AUCi</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15min</td>
<td>↓45%</td>
</tr>
<tr>
<td>0-30min</td>
<td>↓39%</td>
</tr>
<tr>
<td>0-45min</td>
<td>↓35%</td>
</tr>
<tr>
<td>0-60min</td>
<td>↓30%</td>
</tr>
<tr>
<td>0-90min</td>
<td>↓24%</td>
</tr>
</tbody>
</table>

Xylose showed an acute suppressive effect on the postprandial glucose and insulin surges

Furfural

Conversion to furfural is a revenue generator for captive C5 streams not intended for food grade quality

Consumption per region:
- Total 500 kT/yr
  - N-America: 72%
  - Europe: 4%
  - other Asia: 11%
  - Africa: 5%
  - China: 3%
  - RoW: 5%

Consumption by application:
- Major regions; approx. 450 kT/yr
  - Furfurylalcohol: 88%
  - solvent applications: 7%
  - other: 5%
PXLK - High Performance Bioplastic

Xylitol (industrial grade) → Anhydro Xylitol

XLK monomer → Proprietary and Unique Know-How

PXLK Bioplastic → Patents pending

Furfural to FA* → LAE**

Poly Xylitan Levulinate Ketal
* FA – Furfuryl Alcohol
** LAE – Levulinic Acid Ester

PXLK:
Tensile Strength 82 Mpa,
Elongation at break ~30%,
Heat Deflection 100-120 °C

A Substitute for PC (Polycarbonate) and PMMA (Poly(methyl methacrylate))
Setting Standards for Plastics: Benign by Design

• PXLK is:
  – High performance (thermal, tensile, impact resistance, optical)
  – Renewable: non-food C5 sugars from cellulosic biomass
  – Devoid of toxic monomers and additives
  – Degradable via hydrolytic depolymerization with a controlled rate (to fully biodegradable monomers)
  – Recyclable at the monomers level (for making virgin polymer)
Markets

Food Ingredients  Industrial Chemicals  Bioplastics

Applications

- Food Ingredients
- Industrial Chemicals
- Bioplastics
Global Deployment and Feedstock Versatility

- Wheat Straw
- Oat Hulls
- Hardwood
- Corn Cobs
- Sugar Cane Bagasse
- Oil Palm
- Oat Hulls
- Sugar Cane Bagasse
- Wheat Straw
- Oat Hulls
- Wheat Straw
- Corn Cobs
- Rice Hulls
- Sugar Cane Bagasse
- Oil Palm
- Sugar Cane Bagasse
- Sugar Cane Bagasse
- Sugar Cane Bagasse

Optimal Size ● Simpler Design ● Affordable
Enabling Sustainable Future

Join Us in Our Journey!

Thank You

Contact: Olga Selifonova, CEO - olga.selifonova@grasplex.com