Biofine Technology, LLC

Renewable Bioproducts and Biofuels From Wood

Steve Fitzpatrick, Managing Member, Biofine Technology LLC
CELLULOSE

THE BIOFINE PROCESS

CHEMICALS AND FUELS
PRESENTATION OUTLINE

- THE BIOFINE LEVULINIC ACID PROCESS TECHNOLOGY
- BIO-PRODUCTS
- FUELS
- STATUS UPDATE
THE BIOFINE PROCESS
(THE “BIOREFINERY”)

FEEDSTOCKS
“BIOMASS”

CROPS
ARGICULTURAL RESIDUES
CELLULOSIC SLUDGES
WASTE PAPER
WOOD
STARCH
MOLASSES

THE BIOFINE PROCESS

LEVULINIC ACID
FORMIC ACID
FURFURAL
LIGNEOUS CHAR

DOWNSTREAM CONVERSION

SPECIALTY CHEMICALS
COMMODITY CHEMICALS
HERBICIDES PESTICIDES
HEATING OIL BIODIESEL
TRANSPORTATION FUELS BIODIESEL

PRODUCTS
LEVULINIC ACID (LVAC)
A VERSATILE PLATFORM CHEMICAL
Biofine Process - Cellulose Conversion Pathway

First Stage
“Plug Flow”
Reactor
Fast Reaction
(Seconds)

Cellulose
- Sugars
- Intermediates I
- Intermediates II
- Levulinic Acid
  (50wt %)

BYPRODUCTS: Tars
(30 wt%)
Formic Acid (20 wt %)

Second Stage
“Back Mixed”
Reactor

Levulinic Acid

OHC\(\text{OCH}_2\text{OH}\)

Fast Reaction
(Slows)

Second Stage
“Back Mixed”
Reactor

OHC\(\text{OCH}_2\text{OH}\)
CHEMICALS - LEVULINIC ACID (LA)

A NEW VERSATILE PLATFORM CHEMICAL
WITH DERIVATIVE PRODUCTS
IN A BROAD RANGE OF CHEMICAL MARKETS
LEVULINIC ACID: ONE OF THE U.S. DEPARTMENT OF ENERGY’S “SELECT TWELVE” PLATFORM CHEMICALS FROM BIOMASS

<table>
<thead>
<tr>
<th>Succinic Acid</th>
<th>3-Hydroxypropionic Acid</th>
<th>Glutamic Acid</th>
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</thead>
<tbody>
<tr>
<td>Aspartic Acid</td>
<td>Glycerol</td>
<td>4-Hydroxybutyrolactone</td>
</tr>
<tr>
<td>Itaconic Acid</td>
<td>Levulinic Acid</td>
<td>2,5-Furandiacboxylic Acid</td>
</tr>
<tr>
<td>Xylitol</td>
<td>Sorbitol</td>
<td>Glucaric Acid</td>
</tr>
</tbody>
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Today: Levulinic Acid (LA) serving niche markets

2008 Market Dynamics:
- 3,000+ tonnes sold
- Price approx. $3.50/kg
- Chinese producers, largest producer ~1000 tonnes/y
- U.S. was largest export market, Belgium #2, Japan #3

Source: Guangzhou CCM Chemicals Co., Ltd.
Tomorrow: Levulinic Acid (LA) as Platform Chemical

Applications:
- Fuel and fuel additives
- Polymers
- Solvents
- Bio-actives, etc.

Price Target: 50¢/lb (Biofine)

Biofine Technology
FORMIC ACID (BYPRODUCT USES)

- COMMODITY CHEMICAL – ESTABLISHED USES
  PRICE RANGE: $300 TO $650 PER MT

- NEW POTENTIAL USES (FORMIC ACID AND ITS SALTS)
  - REMOVAL OF NOX FROM FLUE GAS AND TAIL PIPE EMISSIONS
  - HYDROGEN CARRIER FOR HYDROGEN FUEL CELLS
  - NON-CORROSIVE ROAD SALT (SODIUM AND CALCIUM FORMATES)
  - LOWER TOXICITY HEAT TRANSFER BRINES (SODIUM FORMATE)
BIOCHAR (BYPRODUCT USES)

- APPROXIMATELY 50% OF WOOD FEEDSTOCK IS BIOCHAR
- HIGH ENERGY CONTENT – 12,500 BTU/LB
- FINELY DIVIDED
- REDUCED ASH PER UNIT OF HEAT OUTPUT
- HIGH CARBON CONTENT – UP TO 70%
- ABILITY TO PROVIDE PROCESS ENERGY REQUIREMENTS ($120/TON)

- NEW POTENTIAL USES:
  - HEATING PELLETS (PREMIUM VALUE COMBINED WITH WOOD)
  - ACTIVATED CARBON
  - CATALYST SUBSTRATE
  - CARBON FIBER
  - GASIFICATION FURNISH
CELLULOSIC BIODIESEL:
ADVANCED BIOFUEL FOR USE
IN
TRANSPORTATION FUELS
AND
COMMERCIAL AND RESIDENTIAL HEATING OIL
Biofuels Options: Second Generation

Food crops 1st generation

Fermentation

1st generation

Ethanol or ETBE

Biomass to liquids or other new processes

2nd generation cellulose

Esterification or hydrotreatment

Esterification or hydrotreatment

Esterification or hydrotreatment

Biomass to liquids or other new processes

Enzymatic hydrolysis or other new processes

Levulinate Esters (Biofine)

Gasoline

Diesel

Biodiesel
ETHYL LEVULINATE:
CELLULOSIC BIODIESEL

A BIODIESEL SUPERIOR TO VEGETABLE-DERIVED BIODIESEL IN SEVERAL WAYS

• REDUCES OR ELIMINATES GUM FORMATION
• INCREASES OXIDATIVE STABILITY
• REDUCES VISCOSITY IN FAME OR OTHER OIL BLENDS
• IMPROVES COLD FLOW PROPERTIES (CFPP)
• IMPROVES CLOUD POINT
• MUTUAL CO-SOLVENCY IN DIESEL AND HEATING OIL
• EXTENDS AVAILABILITY OF FAME IN VERY LARGE MARKETS
• BIOFINE ALLOWS PRODUCTION FROM CELLULOSE
• ENTRY FOR ETHANOL INTO MIDDLE DISTILLATES MARKETS
### SUITABLE FEEDSTOCKS FOR THE BIOFINE PROCESS

<table>
<thead>
<tr>
<th>Energy Crop</th>
<th>Industrial Waste</th>
<th>Agricultural Residues</th>
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</thead>
<tbody>
<tr>
<td>Miscanthus</td>
<td>Sewage</td>
<td>Biomass</td>
</tr>
<tr>
<td>Willow/Poplar</td>
<td>Waste Paper</td>
<td>Straw</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>Paper Sludge</td>
<td>SMC</td>
</tr>
<tr>
<td>Hemp</td>
<td>Municipal Solid Waste</td>
<td>Peat</td>
</tr>
<tr>
<td>Wood and Forest Biomass</td>
<td>Sawmill Waste</td>
<td>Bagasse</td>
</tr>
<tr>
<td>Spartina</td>
<td>Wood</td>
<td>Stover</td>
</tr>
<tr>
<td>Paper pulp</td>
<td>Construction Waste</td>
<td>Manure</td>
</tr>
<tr>
<td>Algae/Kelp</td>
<td>Landfill contents</td>
<td>Brewery Waste</td>
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VALUE PROPOSITION

- SIMPLE, ROBUST, COMPACT ECONOMICAL, ESTABLISHED
- CHEMICAL NOT BIOLOGICAL
- RENEWABLE SOURCE FOR BOTH CHEMICALS AND FUELS
- UTILIZES FORESTRY OUTPUT AND CELLULOSIC WASTES
- BENEFICIAL ADDITIVE FOR BIODIESEL, HEATING OIL, & GASOLINE
- REDUCE LOCAL AND NATIONAL PETROLEUM DEPENDENCE
- REDUCES GREENHOUSE GAS INTENSITY OF LIQUID FUELS
- BENEFICIAL USE OF EXISTING UNDERUTILIZED INDUSTRIAL SITES
UPDATE: WHERE ARE WE NOW?

TECHNOLOGY, MARKET AND FEEDSTOCKS

TECHNOLOGY
• MAJOR ADVANCE IN FEEDSTOCK PREPARATION

FUELS MARKET
• ETHYL LEVULINATE VALIDATION AS BIODIESEL COMPONENT IN HHO
• EXPANDING INTEREST IN DROP-IN HYDROCARBON (U.MAINE, U.CAL DAVIS, OTHERS)

CHEMICALS MARKET
• EXPANDING MARKET FOR LEVULINIC ACID ITSELF
• OTHER CHEMICAL USES - LONGER TERM (DIFFICULTY IN BREAKING INTO MARKET AND FINANCING – “CATCH 22”)

FEEDSTOCKS
• INCREASED INTEREST IN DIRECT USE OF WOOD AND WOOD WASTE
• INCREASED INTEREST IN SLUDGE LANDFILL RECLAMATION
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