BIOCYCLE – Sustainable polymer from sugar cane

PHB INDUSTRIAL S/A

BIOENERGY II
08 - 13 March, 2009
Rio de Janeiro - Brazil
Petro based Products – Life Cycle Assessment

- Oil Extraction
- Plastics Production
- CO2
- Global Warming

Diagram showing the life cycle of petro-based products, from oil extraction to plastics production, with CO2 emissions and global warming effects.
BIObased Products – Life Cycle Assessment

Rescue – 4.400 kg CO2/ton of PHB - Biocycle

Bioplastic Production

Biomass Growth
BIObased Products – Life Cycle Assessment

Positive Environment Impact

Biomass Growth
Biorefinery Concept

- Sugar Cane
- Boilers
- PHB Production
- Final Product
- Polímero
- Molasses
- Energy
- Compost
- Discharge
- Sugar Mill
GHG (GreenHouse Gas) in the sugar cane, sugar and ethanol production

<table>
<thead>
<tr>
<th>Activities 1: Production, harvest and sugar cane transport</th>
<th>kg CO$_2$/Ton of Sugar Cane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+ 425.2</td>
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</table>

<table>
<thead>
<tr>
<th>Activities 2: Industrialization of Sugar Cane: Production of Sugar and Ethanol (45% Sugar, 55% Ethanol)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>-169.0</td>
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<table>
<thead>
<tr>
<th>Activities 3: Final Products utilization (Sugar and Ethanol)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>- 49.4</td>
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</table>

<table>
<thead>
<tr>
<th>Total Avoided Emissions</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>+ 206.8</td>
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<table>
<thead>
<tr>
<th>Average production of sugar cane (ton)</th>
<th>Per Hectare</th>
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<tr>
<td></td>
<td>85,00</td>
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<table>
<thead>
<tr>
<th>Total Avoided Emissions (kg CO$_2$)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>+ 17.578</td>
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Source: Unicamp / CTC - Copersucar
Biocycle is a net CO2 consumer / cleaner, when considered the entire lifecycle

<table>
<thead>
<tr>
<th>Product</th>
<th>CO2 (kg) per Ton of Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHB – Biocycle (from sugar cane)</td>
<td>4.400</td>
</tr>
<tr>
<td>Biopolymer (year 10)</td>
<td>3.086</td>
</tr>
<tr>
<td>Biopolymer (year 3)</td>
<td>1.654</td>
</tr>
<tr>
<td>Biopolymer (year 1)</td>
<td>(1.764)</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>(2.041)</td>
</tr>
<tr>
<td>Polystyrene (general purpose)</td>
<td>(3.017)</td>
</tr>
<tr>
<td>PET Aus</td>
<td>(4.567)</td>
</tr>
<tr>
<td>Nylon 6.6</td>
<td>(7.877)</td>
</tr>
<tr>
<td>Cellulose</td>
<td>(14.363)</td>
</tr>
</tbody>
</table>

Source: Cargill Dow LLC; PHB Industrial Analyses
Historical Prices

Prices Sugar, Corn and Oil

- Light Crude Oil - Continuous Contract
- Corn - Continuous Contract
- World Sugar (CSCE) - Continuous Contract

Base = 100
Energy Balance

Fossil-fuel energy used to make the fuel (input) compared with the energy in the fuel (output)

**Corn Ethanol**
- **Input** (fossil – fuel): 1
- **Output**: 1.3

**Sugar Cane Ethanol**
- **Input** (fossil – fuel): 8.0
- **Output**: 8.0
The Consequence Therefore Is:

- Polymer Production from Renewable Resources
- Minimization of Energy Input from Fossil Resources

Production via „WHITE BIOTECHNOLOGY“
The PHB production consumes only 10% of the energy no renewable used in the PP production process. The renewable energy sources used in PHB production process include the sugar cane, the sugar, the solvent and all the utilities.

During the whole process (Life cycle – Production, use, discharge) the PHB uses almost only renewable energy sources.
BIOCYCLE’s Pilot Plant
Scale 20 m³ Production Reactor
Sugar Cane Field
Sugar Cane Crop
Sugar Cane Crop
Sugar Cane Reception
Sugar
Ethanol
Cogeneration – Renewable Energy
Highlights

- A fully biodegradable biopolymer has been produced from fully renewable materials and source of energy, in an industrial pilot-plant in Serrana / Brazil.

- A set of patents have been filed / published to protect the intellectual capital developed regarding PHB manufacturing and commercialization and also compounds and blends.

- PHB has been successfully tested in blends and compounds to replace traditional plastics, specially PP, PS and PU.

- PHB has been processed in traditional plastics manufacturing equipment to successfully produce parts and pieces to the market – extrusion, thermo forming, injection, coating paper.
Such tests identified the technical characteristics of the base polymer that can be improved through polymer blends and alloys with PHB

- Processing Technology – viscosity, crystallization and reactive extrusion
- Mechanical Properties – tensile strength and impact resistance
- Thermal Properties – heat deflection, melting point, glass transition and decomposition
- Biodegradability – velocity and rate
- Cost
Biocycle® Process Technology

- **Fermentation**
  - **Sugar Açúcar**
  - **Nutrients Nutrientes**
  - **Water Água**

- **Extraction**
  - **Water Água**
  - **Fertilizer Adubo Orgânico**

- **Extrusion**
  - **PHB / PHB-HV (powder / pó)**

- **PHB / PHB-HV (pellets / grânulos)**

- **Injection**
  - **Injection Injeção**

- **Thermoforming**
  - **Thermoforming Termoformagem**

- **Sheets Extrusion**
  - **Sheets Extrusion Extrusão de chapas**

- **Fibers Extrusion**
  - **Fibers Extrusion Extrusão de fibras**

- **Foam**
  - **Foam Espumas**

- **Elastomer**
  - **Elastomer Elastômeros**
As result of investments and technology studies – PHBISA has managed to manufacture pre-commercial scale – a list of products based on PHB

### PHB Based Products

<table>
<thead>
<tr>
<th>Traditional Polymer Replaced</th>
<th>Process</th>
<th>Products</th>
</tr>
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<tbody>
<tr>
<td>Polypropylene</td>
<td>Extrusion</td>
<td>Recipients for nursering crops</td>
</tr>
<tr>
<td></td>
<td>Thermoforming</td>
<td>Automotive parts</td>
</tr>
<tr>
<td></td>
<td>Injection</td>
<td>Parts to crop monitored growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Toys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Packaging parts – caps</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>Thermoforming</td>
<td>Trays for plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disposable cutlery</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>Injection</td>
<td>Elastomers and foams</td>
</tr>
<tr>
<td></td>
<td>Extrusion</td>
<td>– Isolation (construction)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Shoes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Automotive parts</td>
</tr>
<tr>
<td>ABS</td>
<td>Extrusion</td>
<td>Banking cards</td>
</tr>
<tr>
<td></td>
<td>Thermoforming</td>
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</tbody>
</table>

Such products have been obtained through joint efforts with potential clients – Automotive manufacturers, pulp and paper producers, etc...
Polymers, fillers and natural fibers blends with PHB were tested

- Copolyesters
- Poly(caprolactone)
- Poly(lactic acid)
- Wood Powder
- Starch
- Sugar Cane Fiber
- Sisal Fiber
- Others
Polymer
Polymer
Cosmetic Packaging
Packaging Caps

BI CYCLE
Poliuretanos
Fibras
Espuma
Chapas para Termoformagem
Cartões

CARTÕES DERIVADOS DA CANA-DE-ÁCUCAR / CARDS MADE FROM SUGAR CANE

Características:
- Recursos renováveis
- Não libera gases
- Plástico biodegradável
- Sem toxinas
- Cartão plástico produzido com PHB

Biocycle

Main Applications:
- Commercial cards
- Gift cards
- Phone cards

ABnote

Principais aplicações:
- Cartões comerciais
- Cartões de presente
- Cartões pré-pagos
Coating Paper
APLICAÇÕES AUTOMOTIVAS
APLICAÇÕES AUTOMOTIVAS
APLICAÇÕES AUTOMOTIVAS
APLICAÇÕES AUTOMOTIVAS
Braçadeiras para Crescimento Monitorado
Tubetes para Reflorestamento
Seedling Recipient – Eucalyptus

35 days – Nursery fase
Seedling Recipient – Eucalyptus

90 days
Seedling Recipient – Eucalyptus

120 days
Amostras de Produtos
Amostras de Produtos

BIOCYCLE
Certification

- The BIOCYCLE has been certified by Din Certco and AIB-Vinçotte as a biodegradable and compostable material.
NOTIFICATION OF REGISTRATION

The company

PHB Industrial S/A
Fazenda Da Pedra, S/N
14150-000 SERRANA - SP
BRAZIL

hereby receives the confirmation that the product's
Compostable material
of the type
BIOCYCLE 1009
conforms to
DIN EN 13432:2000-12
Certification scheme products made of compostable materials

Registration No.: 7W0079

This Notification of Registration is valid in connection with above stated Registration No. for an unlimited period and becomes ineffective only upon termination.

DIIN CERTCO
Gesellschaft für Konformitätsbewertung mbH
Alteinstraße 56, 12105 Berlin

S. Schau
2007-01-30

DIN CERTCO S.A.
Certification bodies

This certificate is issued in English.

Sergio Van Gestel
Contract Manager

VINCOTTE International

CERTIFICATE FOR AWARDING AND USE OF THE ‘OK COMPOST’ CONFORMITY MARK
No. O 07-140-A
Issued by AIB-VINCOTTE International

For the product(s) described hereafter:
Product group: Biodegradable
Product family: Biodegradable
Mark: BioCycle
Type(s): Biodegradable
Particulate:

Conformity examination applied for by:

PHB Industrial S/A
Fazenda Da Pedra, S/N
14150-000 Serrana - Sao Paulo
BRAZIL.

Criteria for certification:

- AIB test Program with reference OK1: edition C
- ISO 15189:2003, Requirements for packaging intended for composting through biological degradation - Test scheme and evaluation criteria for the sustainability of packaging.

Validity of the certificate:

From 15 February 2007 to 15 February 2012

The products comply with the above mentioned certification criteria, as confirmed by the test report of AIB no: O 009 003 (07 02 2008)

Type examination followed by supervision through verification tests on samples from the distributor's stock.

The conformity of the product is guaranteed by the procedures for awarding and use of the 'OK Compost' conformity mark. This only applies to specimen bearing the 'OK Compost' mark.

This certificate is issued in English.


Philippine Van Gestel
President of the Committee

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Thank you!

Sylvio Ortega Filho

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