Bio-Plastics: Beating Global Warming & Plastics Pollution Crises

- Global Environmental Crisis
- 6 R’s: Reduce, Reuse, Re-cycle
  + Replace, Research, Regulate
- Bio-based & Bio-degradable Plastics
- Applications & Examples

UN ESCO Science Day Nov 12, 2018, Bangkok
K. Jim Jem, Greater China GM, Total Corbion PLA JV
Global Warming & Green House Gases

- **Current Warming:** 1.0°C > average
- **CO₂ Level:** 400 ppm

Data from +/- 2°C Movie

From Earth Systems Research Lab (ESRL)/NOAA

Copenhagen COP 15 2009 & Paris 2015: By 2020, USA shall reduce 17% of the total carbon emission from its 2005 level. China shall reduced 40-45% of its carbon emission per GDP from its 2005 level.

Carbon reduction is the global consent now. With 1.5-2 degree C temp raise, melting of Ever-Frozen land release methane which causes more dramatic Green House effects than CO₂, sea level may increase 61 meters due to ice melting.
Global environmental crises: global warming & plastic waste pollution

- Traditional plastics from petroleum results in global warming and solid waste pollution

Globally 4% of GHG from MSW waste...

Ocean plastic pollution
>80% from Asia...

Source: WEF 2016
Why only 14% of waste is being recycled?

- Multi material packaging
- Difficult cleaning
- Difficult separation
- Separation from color
- Separation from additives
- Loss of quality (degradation)
- Down-cycling (not for food contact)

- Food with high water content not suitable for incineration
- It can go to composting and AD

Garbage in the Sea: 75% Plastics

Global composition of marine litter

- Plastic
- Biotic
- Fisheries (metal)
- Fisheries
- Glass/ceramics
- Metal
- Miscellaneous types
- Paper/cardboard
- Rope
- Textiles/fabrics
- Timber
- Cigarette buds
- Fisheries (plastic)
- Plastic
- Styrofoam
- Other

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Plastics’ Life Span in the sea

HOW LONG UNTIL IT’S GONE?
Estimated decomposition rates of common marine debris items

- Wax Sealant: 3 months
- Garbage Bag: 3 months
- Cigarette Butt: 1–5 years
- Plywood: 1–3 years
- Disposable Diaper: 450 years
- Aluminum Can: 200 years
- Glass Bottle: undetermined
- Fishing Line: 450 years
- Plastic Beverage Holder: 6 months
- Plastic Grocery Bag: 10–20 years
- Wood Socks: 1–5 years
- Styrofoam Cup: 50 years
- Tin Can: 50 years
- Plastic Bottle: 450 years
- Cotton T-shirt: 2–3 months
- Foamed Buoys: 10 years

Estimated individual life of waste items can vary greatly depending on environmental conditions.

Source: NOAA, Natl. Oceanic & Atmospheric Administration, U.S., Marine Debris Team, U.S.

Great Garbage Patches: Handerson Island as an example

Global plastic production: 300 million tons/yr. Total: 9.1 billions tons so far. Only ~10% recycled. 3-8 millions tons/yr dumped into the sea. 83% Plastics pollution in the sea come from 20 countries. China is number one. By 2050, there will be more waste plastics than fishes in the sea.

Handerson Island in the south Pacific Ocean: The most polluted island
28 million pieces of waste plastics, weight 17 tons, 671 pieces/sq meter
Plastic straws and micro-beads: PM 2.5 in the sea (and on the land)

Plastic straws are facing global ban due to that poor turtle. But we only have seen the beginning of a much bigger problem when these ~150 million tons of waste plastics in the sea start to break down into micro-beads. On Oct 24, 2018, European Parliament just proposed to ban all disposssable plastic products.

Micro-beads from cosmetics (facing global bans) or from the broken waste plastics and synthetic plastic fiber from cloth rinsing will cause more and more pollution. Currently, ~600 plastic fiber & micro-beads per kg of sea salts. In Oct 2018, scientists just identified micro-plastic-beads in all tested human bodies.
How to resolve the plastic pollution problems? Traditional vs. New approaches

Traditional approaches:

**Incineration:** Limited due to high costs and air pollution
  e.g. burning the plastic garbage to generate some energy,

**Disposing:** Land filling (popular for under-developed countries)
  e.g. Just bury it.

**Exporting:** (importing of waste plastics banned by China, now Thailand, etc.)
  e.g. Shipping the plastic garbage from rich countries to less developed countries

**Termination:** Not realistic for many applications
  e.g. Banning all traditional non-degradable plastic bags, egg containers,,,, for disposable or even some durable applications

**3 R’s:** Reduce, Re-use, Recycle

**Reduce:** Restricting traditional non-degradable plastics by charging extra fees, etc.
**Re-use:** e.g. Use the same PET water bottle again for personal usage
**Recycle:** e.g. Collect all PET bottles then turn into fiber products
Bio-based Materials or Plastics: From plants (bio-based) instead of petroleum-based. Reduce carbon footprint & global warming. May be bio-degradable (e.g. paper, PLA) or may be not (e.g. bio-PE).

Bio-degradable Plastics: Reduce Solid Waste Pollution. May from petroleum source (e.g. PBAT, PBS) or may from bio-based (PLA, PHA). May produce bio-gas and be composted into fertilizer (back to the nature).
Bioplastics
Represent a fraction of the total plastics market

Bio-PET
- Drop-in replacement for oil-based PET
- Currently only 30% biobased
- Used for bottles

Starch
- Biobased & biodegradable
- Cheap but with low property performance
- Used as a filler for other (bio)plastics

Bio-PE
- Drop-in replacement for oil-based PE
- 100% biobased
- Produced from bio-ethanol

PLA
- Biobased & biodegradable
- High stiffness but brittle
- Transparent

PBAT
- Biodegradable, made from oil
- Primarily used in blends with starch and PLA

PHA
- Early stages of commercialization
- Value as additive/polymer yet to be proven
### PLA carbon footprint & feedstock efficiency

#### Carbon Footprint Emissions from production of common polymers*

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Emissions (kg CO₂ eq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS</td>
<td>2.2</td>
</tr>
<tr>
<td>PET</td>
<td>2.0</td>
</tr>
<tr>
<td>PP</td>
<td>1.7</td>
</tr>
<tr>
<td>LDPE</td>
<td>1.7</td>
</tr>
<tr>
<td>Luminy® PLA</td>
<td>0.5</td>
</tr>
</tbody>
</table>

#### Carbohydrate Usage of Bioplastics

(kg sugar per kg plastic)

<table>
<thead>
<tr>
<th>Biopolymer</th>
<th>Usage (kg sugar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio PET</td>
<td>5.0</td>
</tr>
<tr>
<td>Bio PE</td>
<td>4.0</td>
</tr>
<tr>
<td>PLA</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*Sources: [www.lca.plastics-europe.org](http://www.lca.plastics-europe.org) and Int. Journal Life Cycle Assessment, 'LCA of the manufacture of lactide and PLA…' 3 Aug 2010.*
Start with the best building blocks:

Stereo-chemically pure monomers make the difference!

L-lactic acid $\rightarrow$ L-lactide
D-lactic acid $\rightarrow$ D-lactide

(R,R)-lactide or D-lactide
(S,S)-lactide or L-lactide
(R,S)-lactide or meso-lactide

Building blocks used to make PDLA and PLLA homopolymers
Improved PLA performance for high added value markets

Value & Performance

Time

Durable & consumer products

Single use: High Heat PLA

Single use: Standard PLA

August 29, 2019
PLA (Poly Lactic Acid) in commercial applications today

Cups & lids

Gift cards

Coffee capsules

Packaging films & labels

Consumer goods packaging

Food packaging containers

Bedding

Apparel
Bio-Plastics for food package, cups, bottles, etc

Benefits:
- Recyclable and compostable
- High heat resistance if needed
- Food contact safe. Natural materials.
- Good processing economics, fast speed
- Can be processed on existing polymer lines

Coffee Cups

Fruit Packages

Coffee Capsules

August 29, 2019
Benefits:

- Bio-based and bio-degradable
- Mite resistant, non-allergenic, microbe-static, etc.
- Reduce cotton usage (& virtual water)
- Reduce micro-fiber pollution

Wet wipes

Non-woven bags, tea bags, diapers, etc.
BioPlastic/PLA for Consumer Electronics: cell phone cases, computer housings, etc.

Benefits:

• High heat resistance
• Biobased & bio-degradable
• Excellent high gloss finish
• Excellent impact resistance
• High dimensional stability allows for tight tolerances

Bio-plastic speaker

Touch screen computer

Cell phone case
Benefits:
- Bio-based & biodegradable
- Strength & stability
- Better root growth
- Automation to reduce labor needs
- Thailand: local made for local usage
Benefits:

- Bio-based, biodegradable, and re-cyclable
- Safe for families, schools and studios
- No toxic vapor. Sweet odor.
5th R: Research needed for Other Applications & End-of-life Solutions

- Compounds for semi/durables 3C/automotive parts, tableware, etc.
- Much film, coating on paper, BOPLA, casted film etc…
- Co-polymerization & starch compounding
- Extrusion foaming: cups, instant noodle bowls… (for replacing EPS parts)
- Gas Barrier of PLA bottles: co-extrusion or carbon-coating
- Direct-spinning of PLA fiber for fabrication and non-woven fabrics (diapers, etc.)

**Marine bio-degradability** (temp down to 0-4 degree C)
vs. Industrial composter: 60 degree C, Home composter: 25 degree C
Regulation are required because:
Standards are needed for producers and end users etc to follow
Bio-plastics are more expensive than the traditional plastics.
Dumping is always an easy-dirty way, but with huge hidden costs
Garbage collection and waste treatment need to be paid somehow

United Nations, European Parliament, and >60 Countries e.g. Kenya:
Banning all disposable plastics such as thin plastic bags, straws, etc.
Will BANNING work? (c.f. sex, alcohol and drugs)
Does it help the big picture? (e.g. food waste, water consumption, etc)
Is the current alternatives better on LCA? (vs. glass, paper, etc)
Any better approach? (e.g. bio-plastics plus bio-gas and composting)
The different EOL (End-Of-Life) for Bio-degradable plastics

- Landfill
- Incineration
- Composting
- Bio-Gas
- De-Polymerization
- Recycling
- PLA
For our own Earth
Confidential

China LA/PLA/Fiber phase 2: 100 KT scale

前沿 QianYan
允友成 SUPLA
恒天 长江 Hengtian
中粮 COFCO
富士康 Foxconn

光华伟业 Esun BC
天仁 龙都 LongDu
前沿 QianYan
允友成 SUPLA
恒天 长江 Hengtian
中粮 COFCO
富士康 Foxconn

D: 金玉米 GoldenC
L: 百盛 BaiSheng
L: 华康 HuaKang
L: 金丹 JinDan
中粮格拉特 L: B&G
D/L: 武藏野 MSN
D: 新宁 XinNing

豆丁 BendsL
美亚 AP
曦茂 XiMao
润之缘 RZY
远东化纤 FENC

同杰良 TJL
海正 Hisun
必可成 BWC
呆信 GaoXin
新能新高 FIT/Cha
昌隆 ChLn
Luminy® PLA portfolio: commercially available

Luminy® neat resins are compliant with the most relevant regulations and requirements related to bioplastics:

- EU food contact applications (EC No. 1935/2004 and No. 10/2011)
- EN13432 standard for industrial composting (OK Compost & Seedling)
- Biobased content 100% (EN16785-1)
- REACH compliant
- Reduced carbon footprint: LCA study available
- Made from European sugar beet and Thai sugarcane: these are always GMO-free crops

PLA L105  High flow for injection molding
PLA L130  Medium flow for injection molding or fiber spinning
PLA L175  High viscosity for film extrusion, thermoforming or fiber spinning
PLA LX175 High viscosity, amorphous, transparent for extrusion/thermoforming
PDLA D070 Nucleating agent for PLA homopolymer resins
PDLA D120 Medium viscosity PDLA homopolymer
PLA homopolymers
The secret to obtaining high heat PLA

PLLA and PDLA homopolymers:
• Crystallize fast = improve processing economics
• Improve heat performance

PLA technology from Total Corbion PLA can replace PS, PP and ABS-like materials in applications where heat performance is a key requirement.
Total a global leader in fossil energy and plastics is since years active in and directs a significant research effort towards PLA.

Corbion the global leader in Lactic Acid is invested in a Lactide plant and built expertise in PLA over the past years.

On March 2nd 2017 Total and Corbion signed an agreement joining forces and forming a 50/50 JV called Total Corbion PLA.

The 75 kt Lactide plant will be part of the JV and a 75 kt/a PLA production plant will be constructed.
To continue to serve our current Lactide customers, the Lactide capacity will be increased to 100 kt/a.
Both plants will be operational in H2 2018 and are able to produce any grade between 90% to 100% optical purity.
Two parent companies with complementary strengths

<table>
<thead>
<tr>
<th>Position</th>
<th>World’s 4th largest oil company</th>
<th>World’s largest lactic acid producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headquarters</td>
<td>Courbevoie, France</td>
<td>Amsterdam, the Netherlands</td>
</tr>
<tr>
<td>Revenue</td>
<td>$ 150 B</td>
<td>$ 970 M</td>
</tr>
<tr>
<td>Employees</td>
<td>96,000</td>
<td>1,700</td>
</tr>
<tr>
<td>Profit</td>
<td>$ 6 B</td>
<td>$180 M</td>
</tr>
<tr>
<td>Main products</td>
<td>Oil &amp; Gas, Solar &amp; Bioenergy</td>
<td>Food Ingredients, Biochemicals,</td>
</tr>
<tr>
<td></td>
<td>Commodity &amp; Specialty</td>
<td>Bioplastics, Biomedical</td>
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<tr>
<td></td>
<td>Chemicals</td>
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</tbody>
</table>
Our role in the PLA value chain

Technology Push
- Develop PLA polymerization
- Work with partners on PLA App’s
- Support conversion of PLA

Market Pull
- PLA promotion & communication
- Create sustainability awareness
- Work with leading Corps & (N)GOs

From 2018

Total - Corbion works with - and supports all players along the value chain
Corbion on track to forward integrate into PLA

What we will build:

- **PLA polymerisation:** 75 kTpa – est. capex €65M
- **Lactide extension:** +25 kTpa – est. capex €20M
  - Add distillation capacity to our existing crystallization plant to enable production of standard PLA
- **Secure supply to lactide customers**

**Timeline:** Operational in 2H 2018
**Location:** Rayong, Thailand
Total Corbion PLA: a 50/50 PLA joint venture

- The JV produces and markets PLA (Poly Lactic Acid) resins and lactides
- Total Corbion PLA launched operations 02 March 2017, all regulatory approvals completed
- The JV owns the PLA polymerization plant with a global capacity of 75 kTpa, currently under construction on the Corbion site in Rayong, Thailand
- Corbion’s existing PLA business and lactide production unit migrated to the JV
- Corbion supplies the lactic acid necessary for the production of PLA and lactide
- Your previous Corbion contact remains your key contact person.
Building a world scale PLA plant

**Capacity**  75 kTpa  
**Situation**  Under construction, next to the world’s largest lactic acid and lactide plants  
**Location**  Rayong, Thailand  
**Timeline**  Start of operations 2nd half 2018  
**Status**  Groundbreaking ceremony took place 9 November 2016, construction is ongoing
Growth of PLA Market:

Jem’s Law: Doubled every 3-4 years!

PLA Sales volume = 10 KT x 2

Estimation based on 26% annual growth

NatureWorks 70 KT
Hisun 5 KT
NW + 70 KT
Synbra 5 KT
COFCO 10 KT
Hisun 50 KT
SUPLA 10 KT
(2003-2009)/3

Total Corbion + 75 KT
Hengtian Fiber + 50 KT
NW + 70 KT?
COFCO + 20 KT?
Hisun + 50 KT
265 KT
190 KT
160 KT
145 KT
NatureWorks 70 KT
Hisun 5 KT
NW + 70 KT

(pilot: Yangtze, TJL, Esun, Jiuding, Sulzer, Udhe, etc)
Advantages of Total Corbion’s PLA supply chain

• Made from renewable raw materials
• Biodegradable/Compostable EN13432
• Recyclable
• Favorable CO₂ footprint
• Made from non-GMO raw materials
• High heat performance
• Commercially available
• Offers a unique branding opportunity
Key commercial contacts at Total Corbion PLA

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