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
Current Warming: 1.0°C > average

CO₂ Level: 400 ppm

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 result 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

© AWI-LITTERBASE
Plastics’ Life Span in the sea

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

- Waxed Cotton: 3 months
- Plastic Grocery Bag: 10-20 years
- Cigarette But: 1-5 years
- Plywood: 1-3 years
- Glass Bottle: Undetermined
- Tin Can: 50 years
- Plastic Beverage Holder: 400 years
- Disposable Diaper: 450 years
- Aluminum Can: 200 years
- Fishing Line: 600 years
- Photo-degradable Beverage Bottle: 6 months
- Photo-degradable Beverage Bottle: 6 months
- Fruit Salad: 2-4 months
- Cotton Tote: 2-3 months
- Styrofoam Cup: 50 years
- Wool Socks: 1-5 years
- Foam Burger 50 years

Estimated decomposition times depend on product composition and environmental conditions.

Source: NOAA National Marine and Atmospheric Administration, US - Pacific Marine Environmental Laboratory, US
Sponsor: Daniel Lay, University of California, Santa Cruz

November 13, 2018
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 Nightmare for Marine lives

November 13, 2018
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 disposable 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 foot print & 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

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1 million tons sold in 2017

<table>
<thead>
<tr>
<th></th>
<th>kTons</th>
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<tbody>
<tr>
<td>Bio-PET 30%</td>
<td>300</td>
</tr>
<tr>
<td>Starch</td>
<td>250</td>
</tr>
<tr>
<td>PLA</td>
<td>200</td>
</tr>
<tr>
<td>Bio-PE</td>
<td>150</td>
</tr>
<tr>
<td>PBAT</td>
<td>100</td>
</tr>
<tr>
<td>Bio-PA</td>
<td>50</td>
</tr>
<tr>
<td>Cellulose</td>
<td>50</td>
</tr>
<tr>
<td>PHA</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
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</table>

November 13, 2018
PLA carbon footprint & feedstock efficiency

Carbon Footprint Emissions from production of common polymers*

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Carbon Footprint (kg CO₂ per kg polymer)</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>
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</table>

Carbohydrate Usage of Bioplastics

(kg sugar per kg plastic)

<table>
<thead>
<tr>
<th>Bioplastic</th>
<th>Carbohydrate Usage (kg sugar per kg plastic)</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>
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</table>

Start with the best building blocks:

Stereo-chemically pure monomers make the difference!

L-lactic acid → L-lactide
D-lactic acid → 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

- Single use: Standard PLA
- Single use: High Heat PLA
- Durable & consumer products

Value & Performance

Time

November 13, 2018
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

Tablewares
Benefits:

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

BioPlastics/PLA fibers for apparels, fillers, non-woven bags, etc.

Wet wipes

Non-woven bags, tea bags, diapers, etc.
Benefits:

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

Cell phone case

Bio-plastic speaker

Touch screen computer

BioPlastic/PLA for Consumer Electronics: cell phone cases, computer housings, etc.
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.
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 noodles 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
6th R: Regulation (instead of just Banning)

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

- Recycling
- PLA
- De-Polymerization
- Landfill
- Incineration
- Composting
- Bio-Gas
For our own Earth
China LA/PLA/Fiber phase 2: 100 KT scale
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

<table>
<thead>
<tr>
<th>PLA L105</th>
<th>PLA L130</th>
<th>PLA L175</th>
<th>PLA LX175</th>
<th>PDLA D070</th>
<th>PDLA D120</th>
</tr>
</thead>
<tbody>
<tr>
<td>High flow for injection molding</td>
<td>Medium flow for injection molding or fiber spinning</td>
<td>High viscosity for film extrusion, thermoforming or fiber spinning</td>
<td>High viscosity, amorphous, transparent for extrusion/thermoforming</td>
<td>Nucleating agent for PLA homopolymer resins</td>
<td>Medium viscosity PDLA homopolymer</td>
</tr>
</tbody>
</table>
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 2\textsuperscript{nd} 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 4\textsuperscript{th} 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 Commodity &amp; Specialty Chemicals</td>
<td>Food Ingredients, Biochemicals, Bioplastics, Biomedical</td>
</tr>
</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
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

Jem’s Law: PLA volume doubled every 3-4 years! (calendar year-2003)/3

PLA Sales volume = 10 KT × 2

NatureWorks 70 KT
Hisun 5 KT
NW + 70 KT
Synbra 10 KT
SUPLA 10 KT
COFCO 10 KT
Hengtian Fiber + 50 KT?
NW + 70 KT?
COFCO + 20 KT?
Hisun + 50 KT
Total Corbion + 75 KT

Estimation based on 26% annual growth

11/13/2018
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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