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 ESCAP Science Day Nov 12, 2018, Bangkok
K. Jim Jem, Greater China GM, Total Corbion PLA JV

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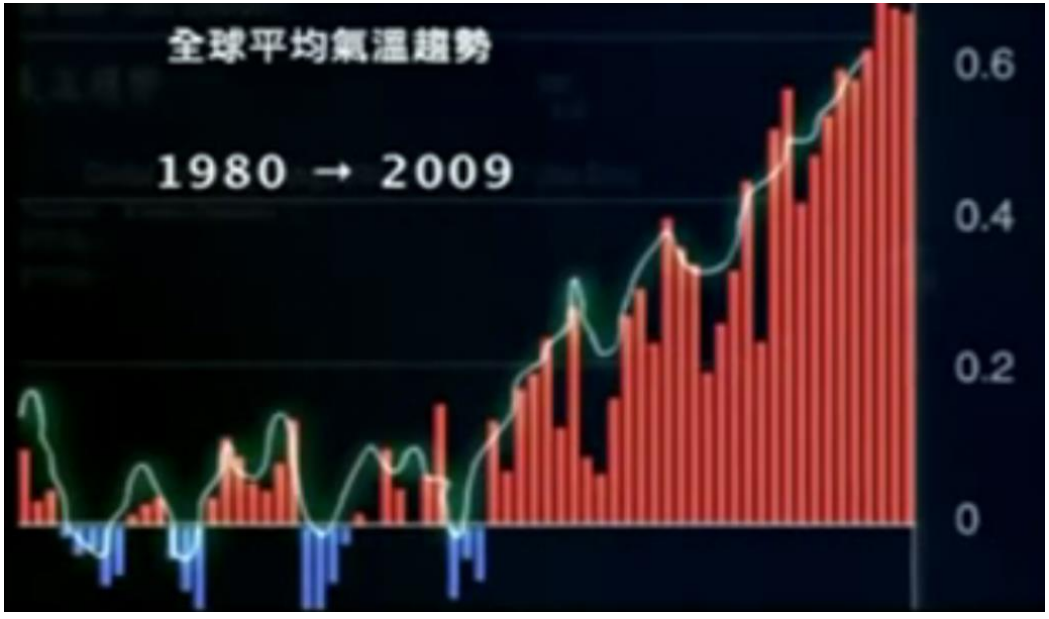
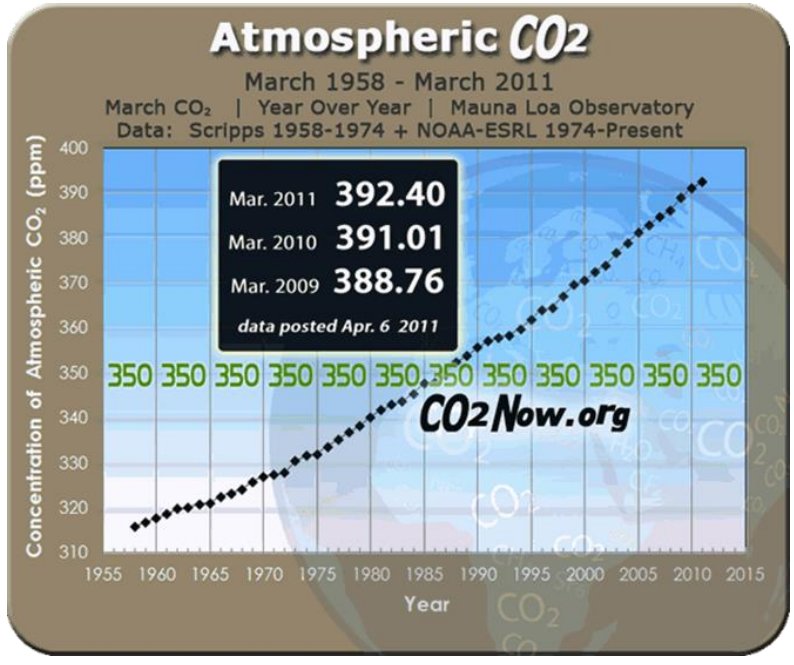
Global Warming & Green House Gases

- *Current Warming: 1.0 C > average*



Data from +/- 2 C Movie

- *CO_2 Level: 400 ppm*



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

Global warming

Globally 4% of GHG from MSW waste…

Ocean plastic pollution

>80% from Asia…

Source: WEF 2016

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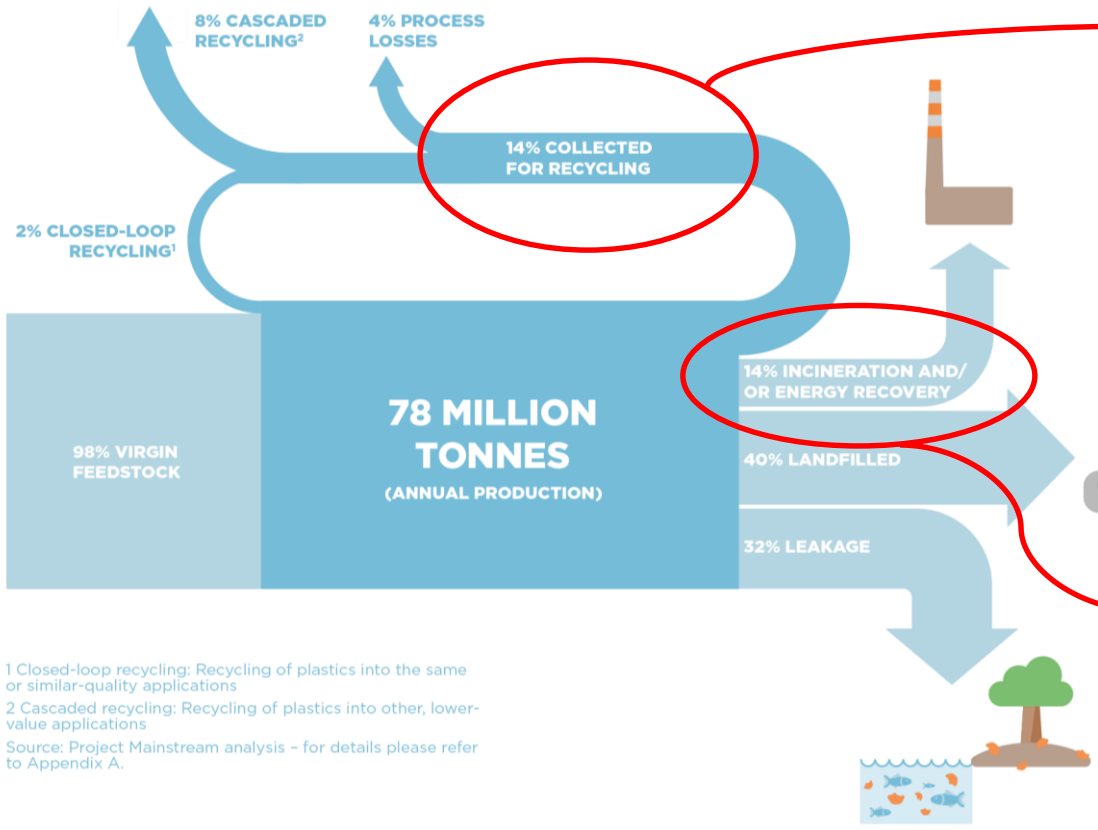
Why only 14 % of waste is being recycled ?



- 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

Adapted from Source: World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy – Rethinking the future of plastics* p.27 "Global flows of plastic packaging materials in 2013" (2016, http://www.ellenmacarthurfoundation.org/publications).

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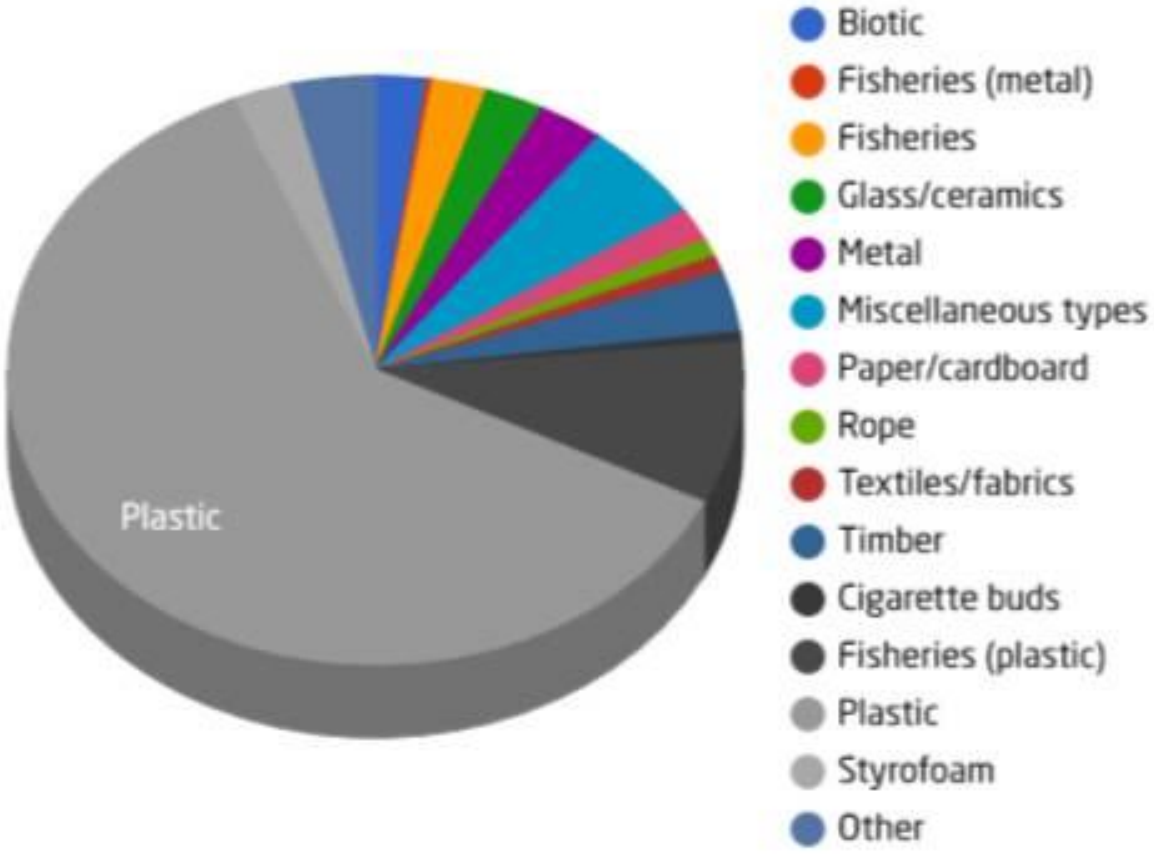
Garbage in the Sea: 75% Plastics

Global composition of marine litter



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Plastics' Life Span in the sea

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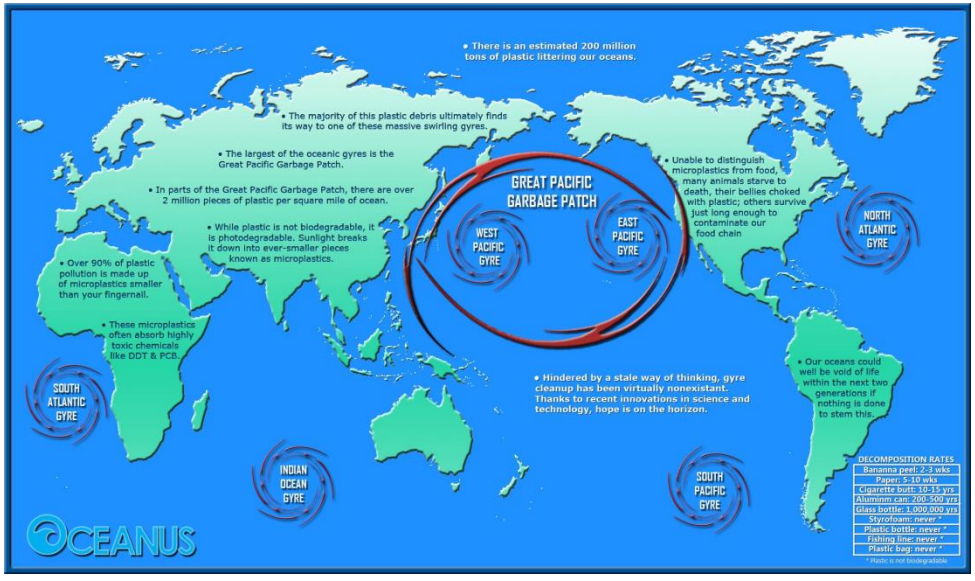
Great Garbage Patches:
Handerson Island as an example

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

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Plastic Nightmare for Marine lives

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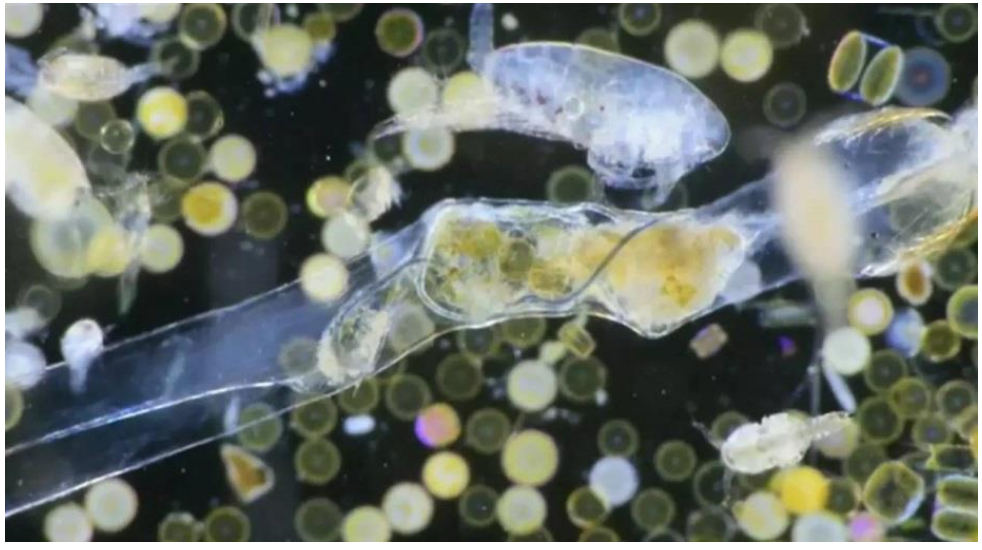
Plastic straws and micro-beads: PM 2.5 in the sea (and on the land)

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 dispossable 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.

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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 (polular 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
Recyle: e.g. Collect all PET bottles then turn into fiber products

4th R: Replacement (by bio-plastics)

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

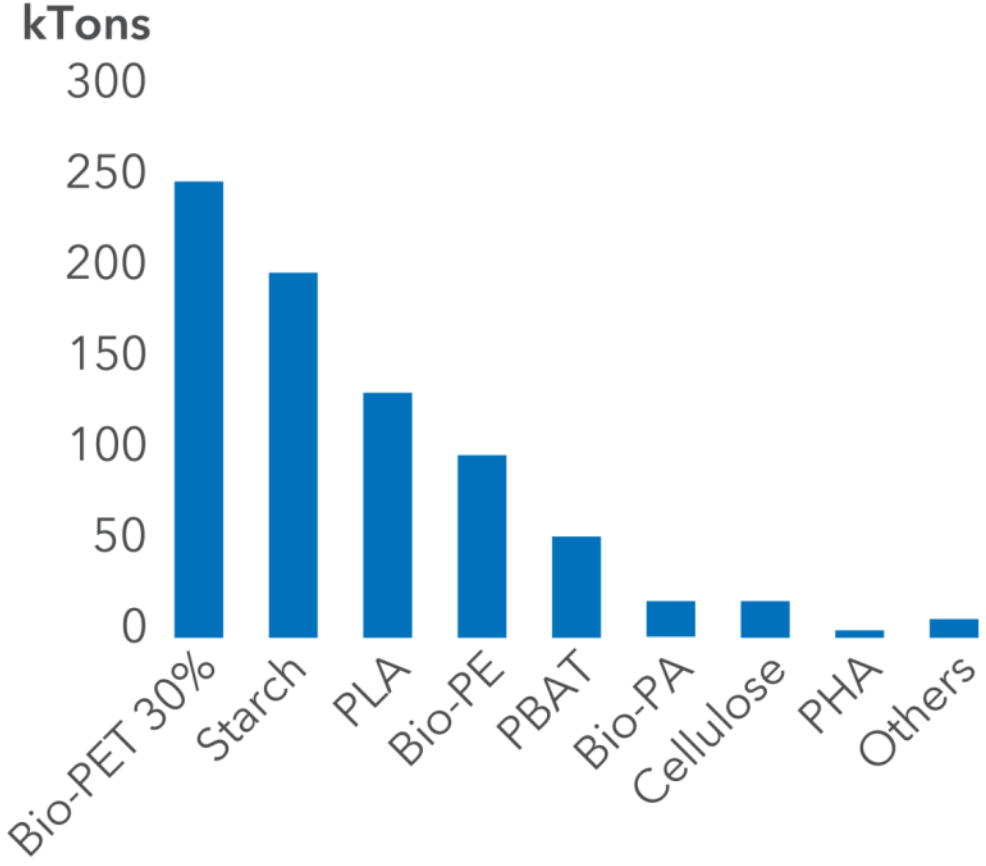
PBAT

- 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

1 million tons sold in 2017



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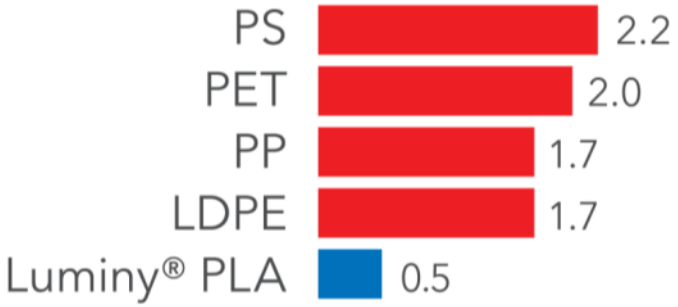
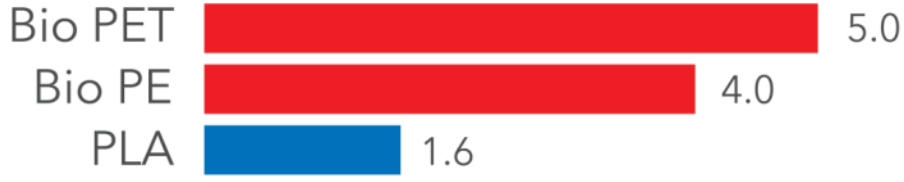
PLA carbon footprint & feedstock efficiency

Carbon Footprint Emissions from production of common polymers*



Carbohydrate Usage of Bioplastics

(kg sugar per kg plastic)



Sources: www.lca.plsaticseurope.org and Int. Journal Life Cycle Assessment, '*LCA of the manufacture of lactide and PLA…'* 3 Aug 2010.

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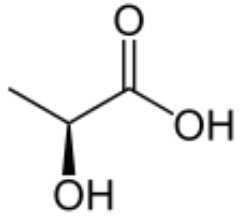
Start with the best building blocks:

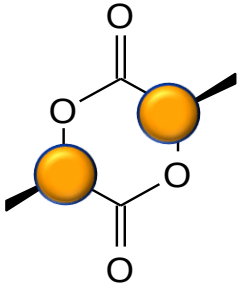
Stereo-chemically pure monomers make the difference!

L-lactic acid → L-lactide

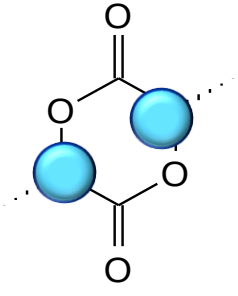
D-lactic acid → D-lactide



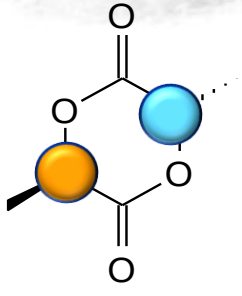
L-lactic acid



(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

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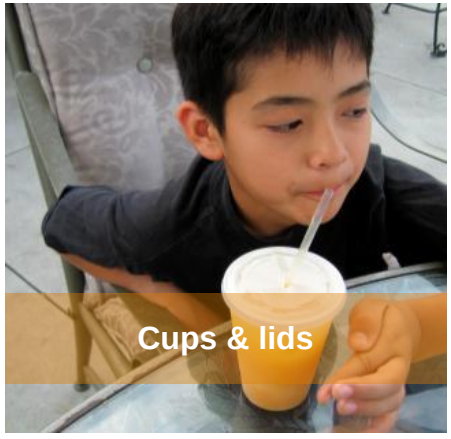
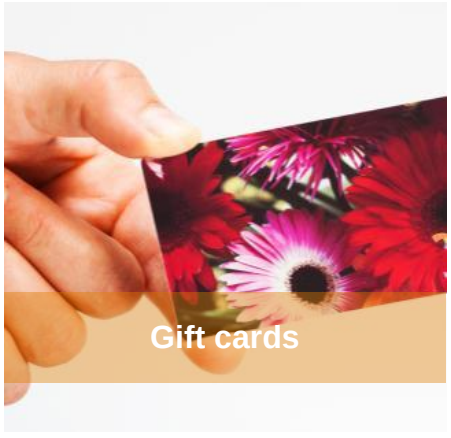
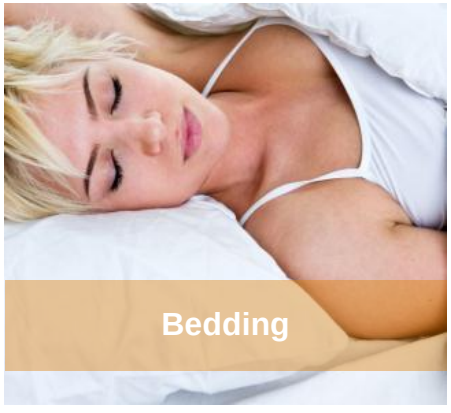
Improved PLA performance for high added value markets

PLA (Poly Lactic Acid) in commercial applications today







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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

Tablewares

Coffee Cups

naturesse®

Fruit Packages

WinGram

Coffee Capsules

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

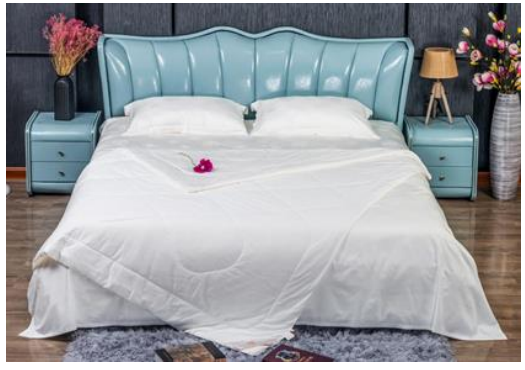
Benefits:

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

Apparels & filler

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

Cell phone case

纳通 NATON

Bio-plastic speaker

Touch screen computer

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BDP/PLA/Starch for Agriculture applications injection molded root trainers for trees/rice

Benefits:

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

Thai Rubber Association

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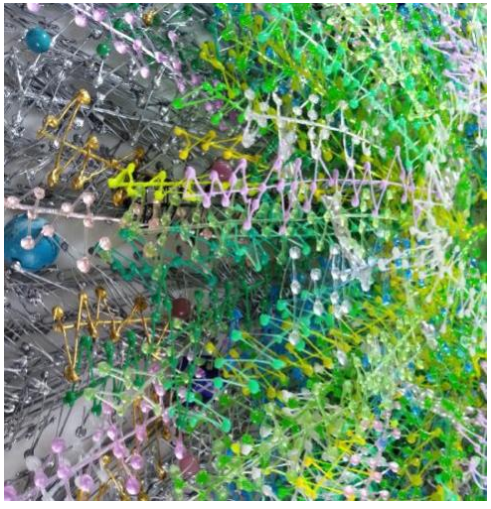
BDP/PLA for 3D printing: Medical, Culture, Art & Design

Benefits:

- Bio-based, biodegradable, and re-cyclable
- Safe for families, schools and studios
- No toxic vapor. Sweet odor.



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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

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

Landfill

Incineration

EOL for Bio-Plastics

PLA

De-Polymerization

Bio-Gas

Composting

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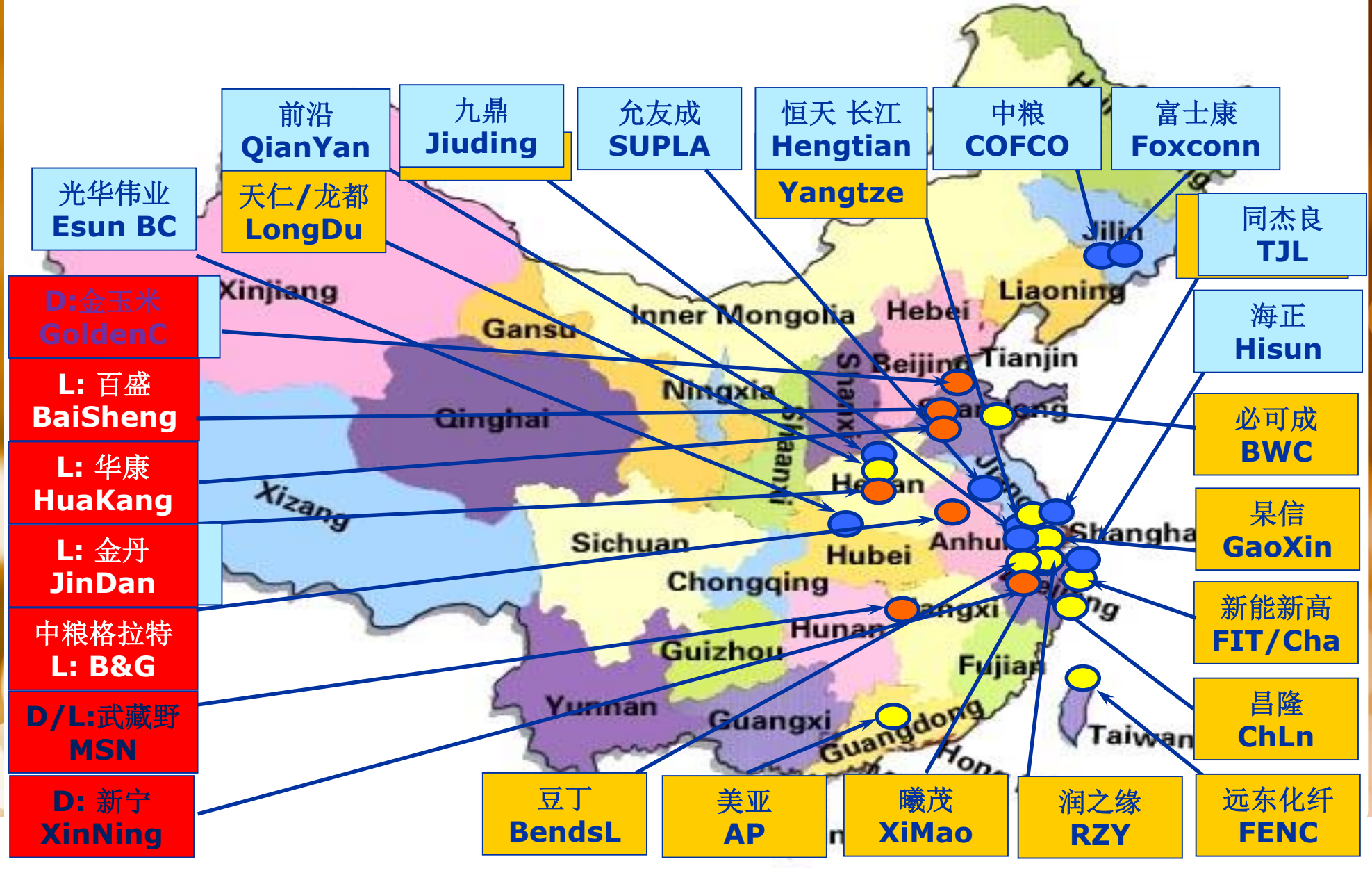
For our own Earth

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



Key China BioPlastic Projects

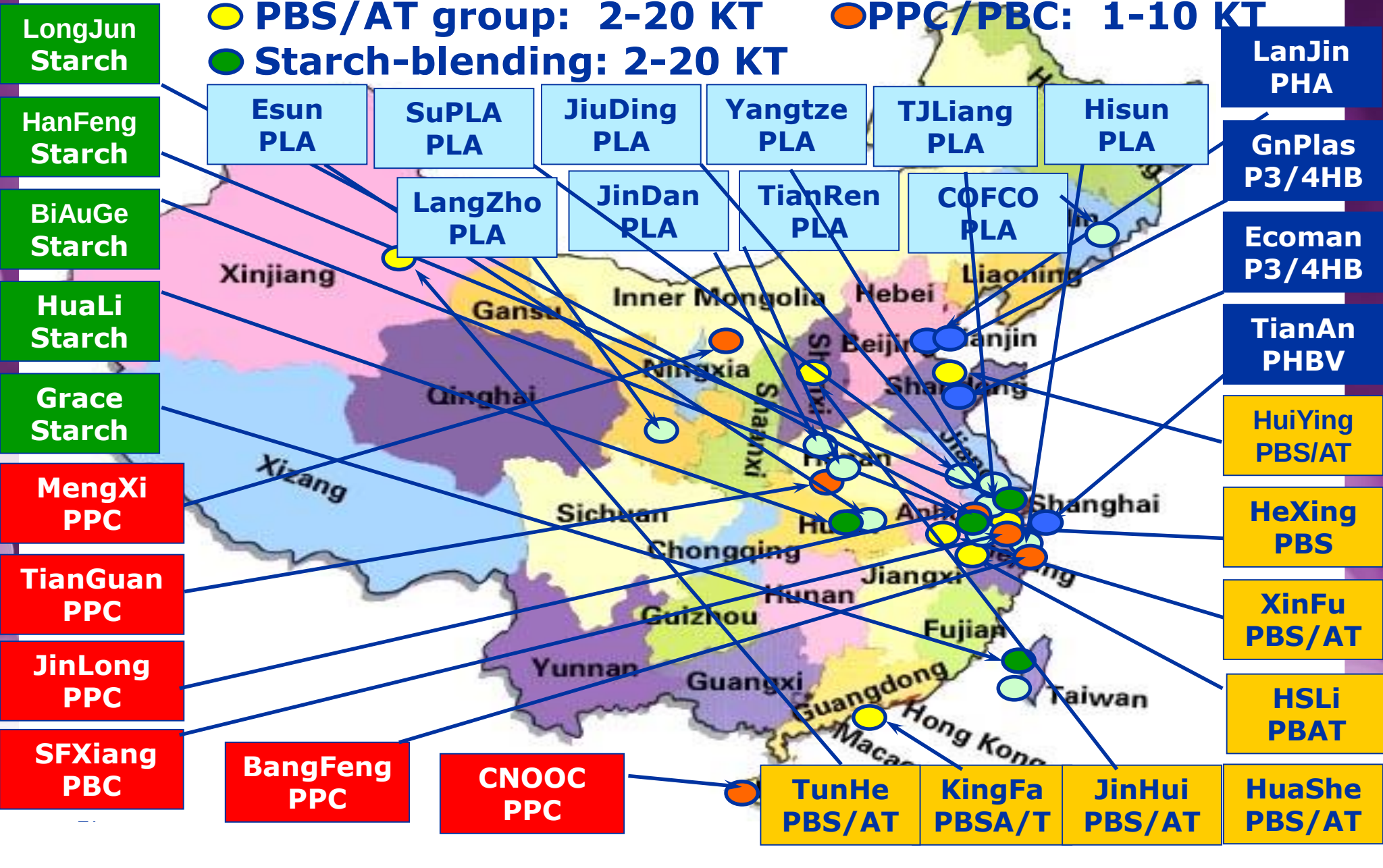
PLA: 1-5-10 KT

PBS/AT group: 2-20 KT

Starch-blending: 2-20 KT

PHBV group: 1-10KT

PPC/PBC: 1-10 KT



Luminy® PLA portfolio: commercially available

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

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

OK compost S478 VINÇOTTE

biobased %

7W2030 compostable

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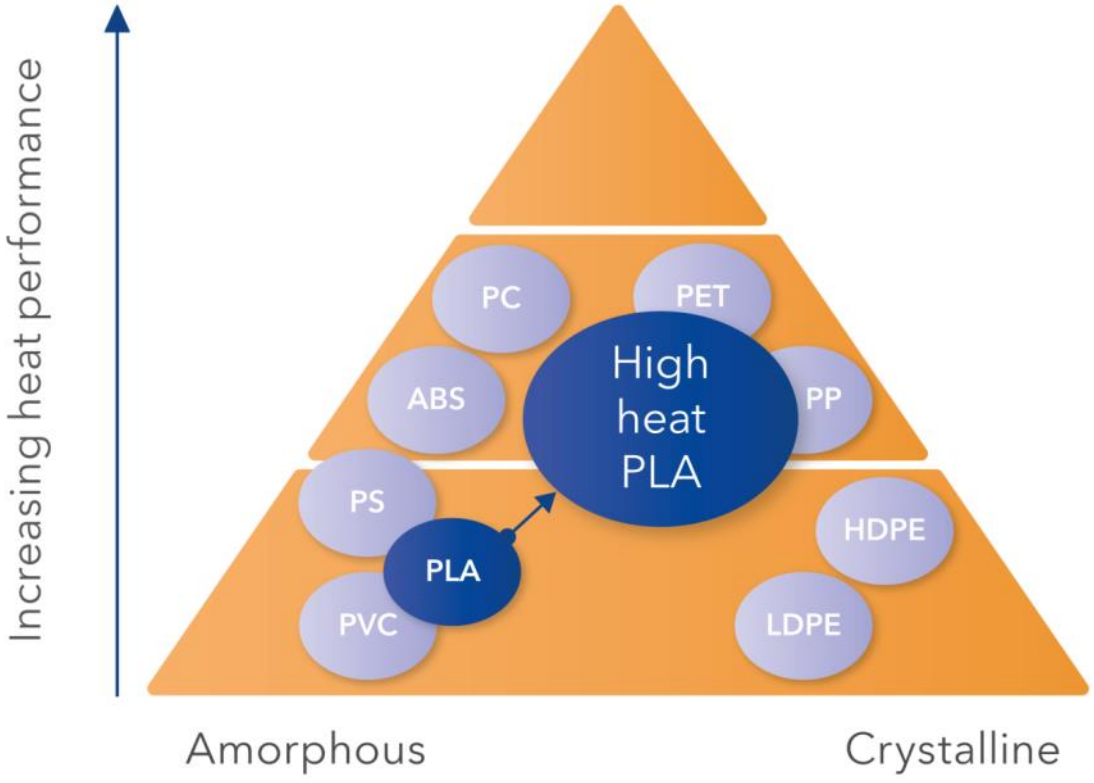
PLA homopolymers

The secret to obtaining high heat PLA

PLLA and PDLA homopolymers:

- Crystallize fast = improve processing economics
- Improve heat performance



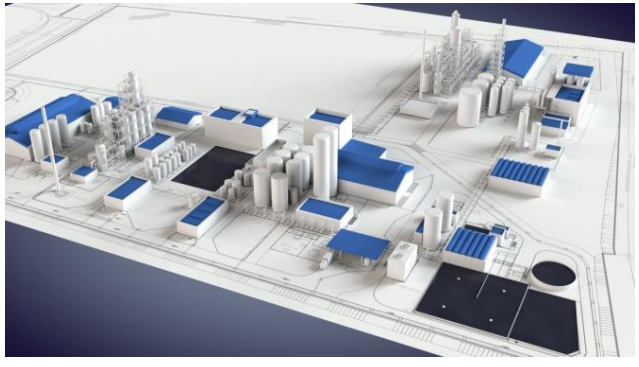
PLA technology from Total Corbion PLA can replace PS, PP and ABS-like materials in applications where heat performance is a key requirement.

Total Corbion PLA - the rationale

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

	TOTAL	Corbion
Position	World's 4th largest oil company	World's largest lactic acid producer
Headquarters	Courbevoie, France	Amsterdam, the Netherlands
Revenue	$ 150 B	$ 970 M
Employees	96,000	1,700
Profit	$ 6 B	$180 M
Main products	Oil & Gas, Solar & Bioenergy Commodity & Specialty Chemicals	Food Ingredients, Biochemicals, Bioplastics, Biomedical

Our role in the PLA value chain

- Development of PLA supply chain
- Development of markets and applications

Sugar feedstock → LA production → Lactide & PLA production → Compound production → Conversion to products → Brandowner → Retailer → Consumer

NGOs & Government

From 2018

Technology Push

- Develop PLA polymerization
- Work with partners on PLA App's
- Support conversion of PLA

Market Pull

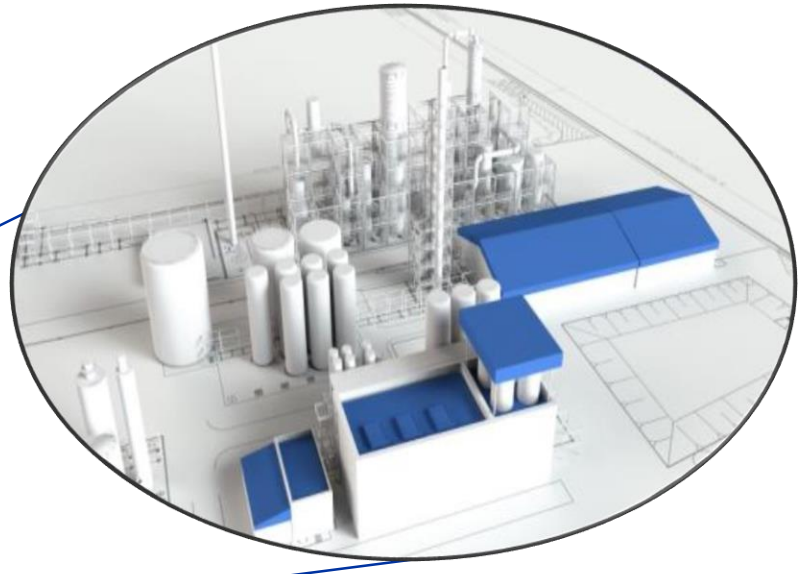
- PLA promotion & communication
- Create sustainability awareness
- Work with leading Corps & (N)GOs

Total - Corbion works with - and supports all players along the value chain

Corbion on track to forward integrate into PLA

What we will build:

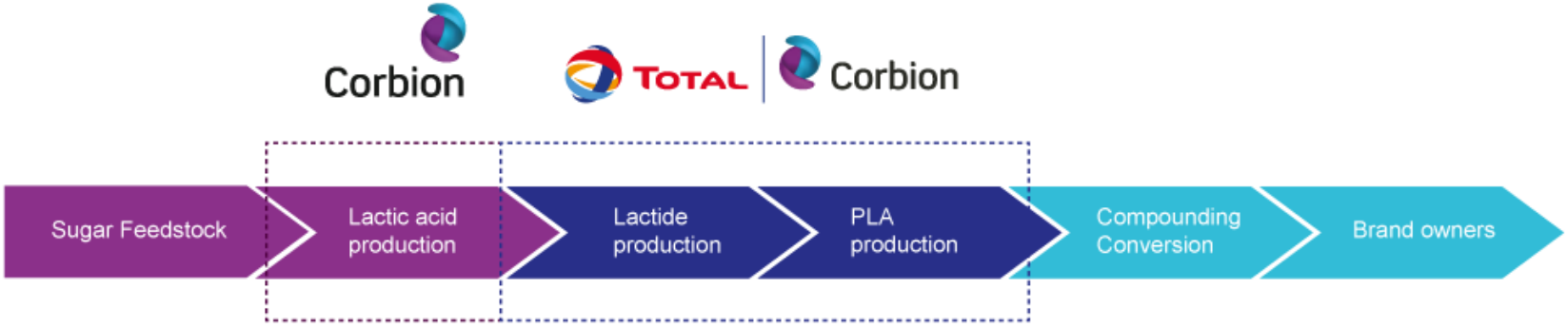
- **PLA polymerisation:** 75 kTpa – est. capex € 65M
- **Lactide extension**: +25 kTpa – est. capex € 20M
  - Add distillation capacity to our existing crystallization plant to enable production of standard PLA
  - **Secure supply to lactide customers**



- **Timeline**: Operational in 2H 2018
- **Location**: Rayong, Thailand

Total Corbion PLA: a 50/50 PLA joint venture

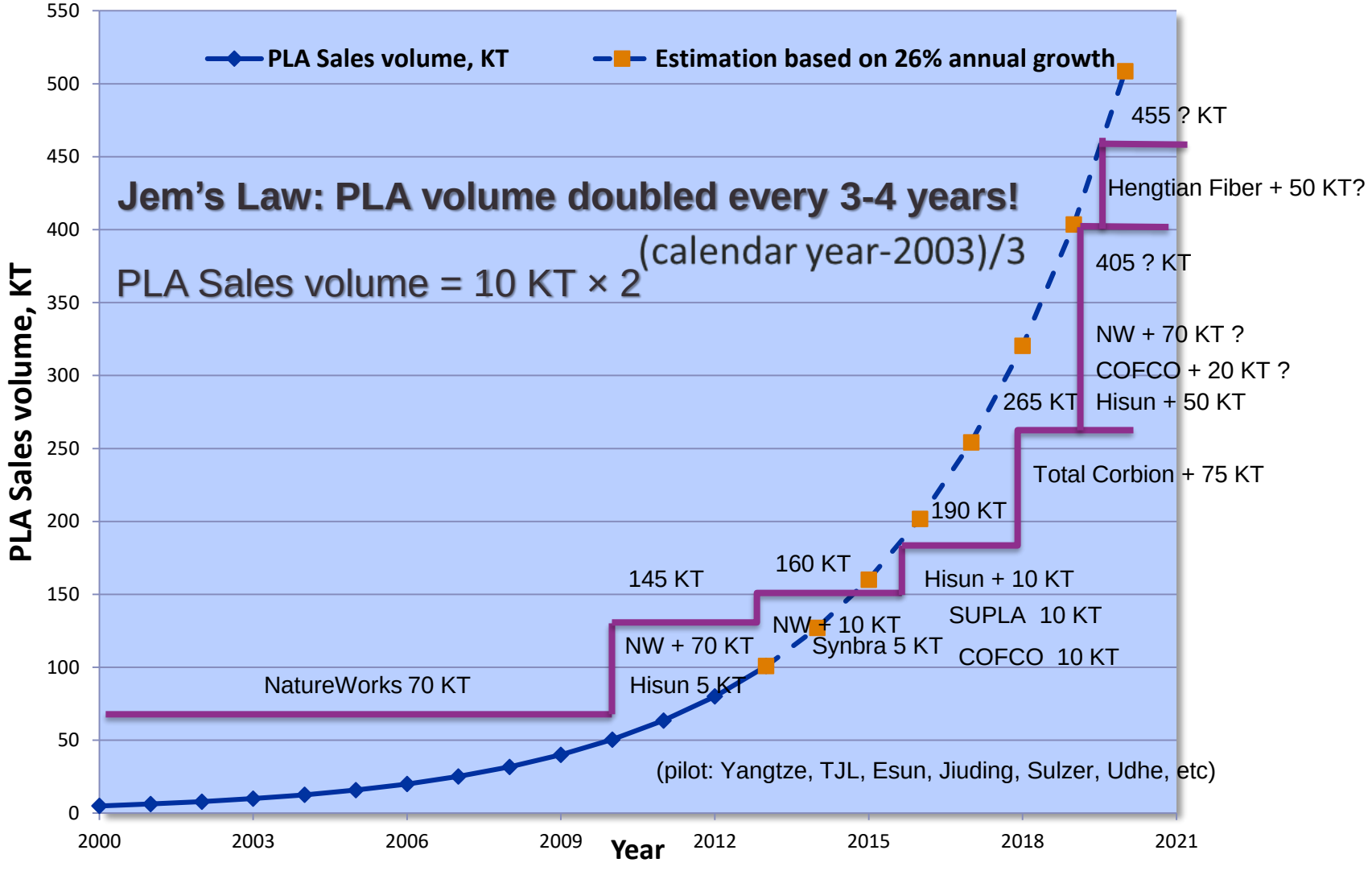
- The JV produces and markets PLA (Poly Lactic Acid) resins and lactides
- Total Corbion PLA launched operations 02 March 2017, all regulatory approvals completed
- The JV owns the PLA polymerization plant with a global capacity of 75 kTpa, currently under construction on the Corbion site in Rayong, 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



Advantages of Total Corbion's PLA supply chain

- Made from renewable raw materials
- Biodegradable/Compostable EN13432
- Recyclable
- Favorable CO_2 footprint
- Made from non-GMO raw materials
- High heat performance
- Commercially available
- Offers a unique branding opportunity

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Key commercial contacts at Total Corbion PLA

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