BioPlastics for our Cleaner Earth

"Global Forum on Human Settlements"

17th Annual Conference 2022/12/15-16

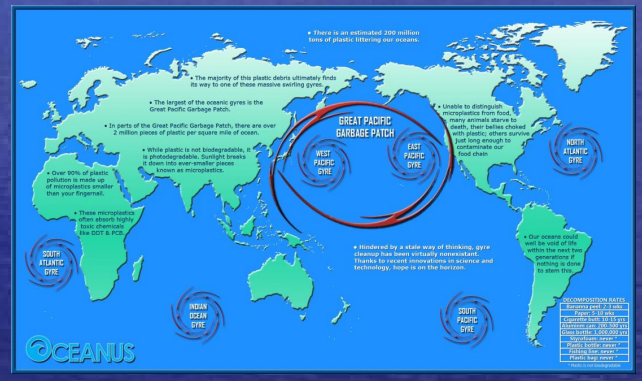
- Enviromental Crises: Global Warming & Plastic Pollution
- Banning vs. Replacement by Bio-Plastics/Materials
- Regulation & Government Policy for SUP
- Research, Applications, and Market Growth for BDP
- Current Policy & Planned BDP Projects in China
- End-of-Life Treatment for Sustainable Development

K. Jim Jem, Ph.D., P.E.
Senior Advisor of GFHS
China Academy of Science, CNITech
Jim_Jem@126.com, +86 13661595602

Environmental Crisis 1 : Plastics Pollution

~ 6 Billion Tons of plastic waste remains on the Earth slowly breaking down in ~100-500 yrs

> 100-200 million tons of Plastics in the Sea. > 8-12 million tons/year added.



Solution: Using Bio-Degradable Plastics/Materials, e.g. PBAT/PLA/PHA/PBS/PGA /Starch...

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November 28, 2022

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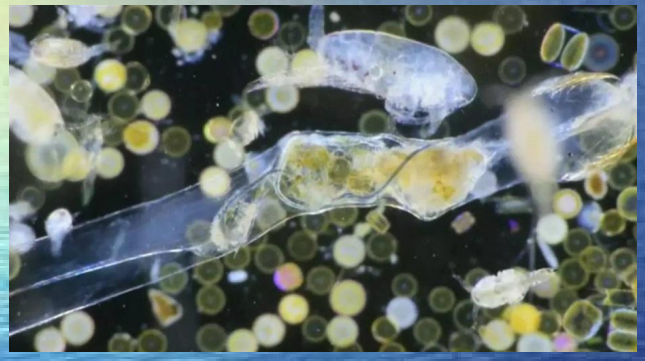
Micro-Plastics Pollution

Micro-plastics/polymer particles in air/land/water eventually enter food chain & human body

22 human blood samples contained ave. 1.6μg/ml micro-plastics
90% PET micro-plastics as 10% of the spider web weight



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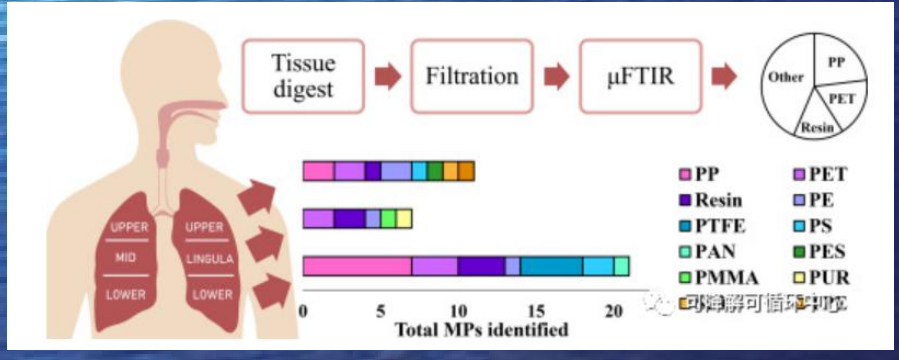
Science of The Total Environment
Volume 831, 20 July 2022, 154907

Detection of microplastics in human lung tissue using μFTIR spectroscopy



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Volume 832, 1 August 2022, 155008

Plastic in the air?! - Spider webs as spatial and temporal mirror for microplastics including tire wear particles in urban air

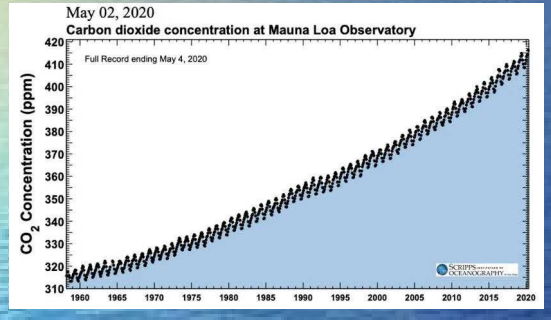
Solution: Using Nature/Marine composting Plastics/Materials, e.g. PHA/PGA /Starch/ Paper...

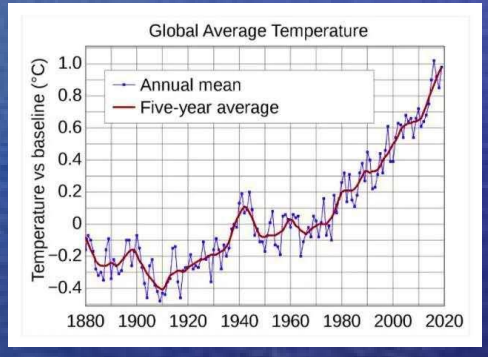
Environmental Crisis 2 : Global Warming

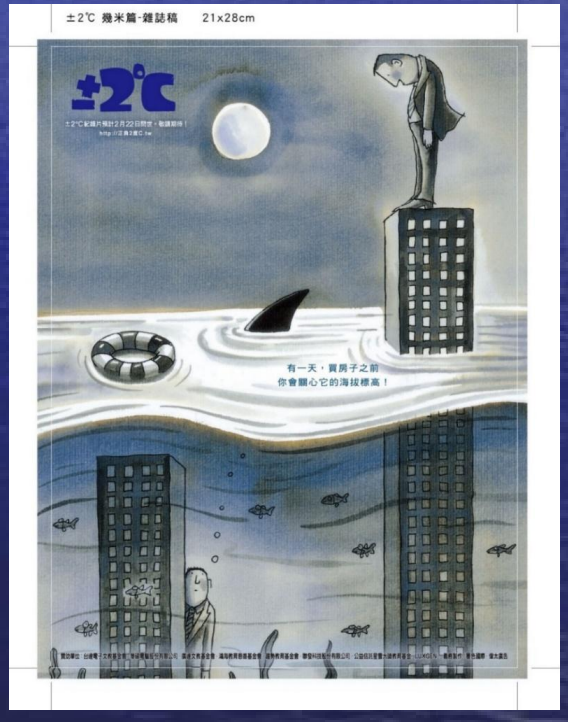
Green House Gases from Fossil-origin

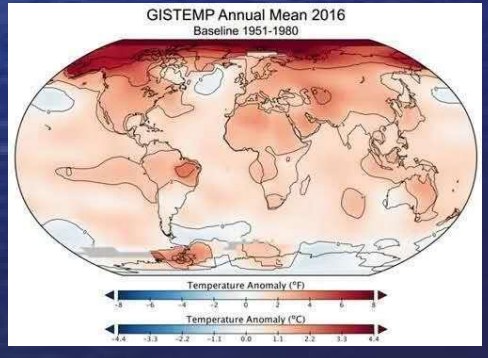
CO_2 > 420 ppm, up from 280 ppm before Industry Revolution.
Global Ave. Temp up > 1.2° C

CO_2>450 ppm & Temp up>1.5° C by ~2050. Sea Level may go up >60 m









Using Bio-based or Cabon-Captured Plastics/Materials: e..g. bio-PE, FDCA/PEF, PLA, PGA

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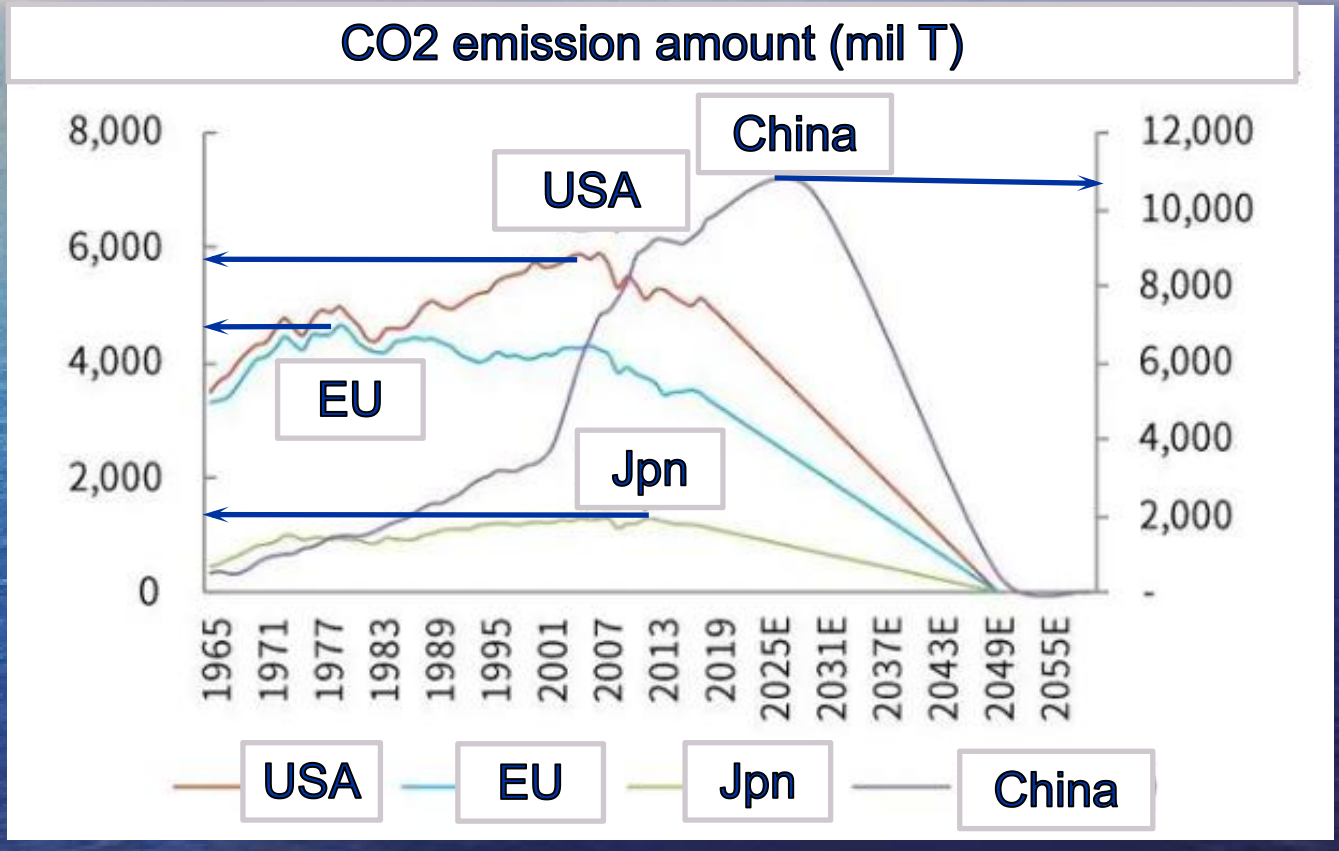
China: Largest CO2 Emission Country

(largest only by total amount, not by per capita)
Pledged to reach Carbon Peak/Neutral by 2030/2060



Each China province/city had received CO2 emission quota to meet the goals/timelines

2018/6：UN called to “Beat Plastic Pollution”

Old ways and the 3 R’s do not work effectively

How to resolve the problem?

Old ways：Burn/Incinerate, Dump/Landfill, Export

Burning: ~300-500 ° C. Imcomplete breakdown, Serious air pollution.

Incineration: >1000 ° C. High enegy consumption. CO2 emission.

Dumping: Long term pollution on air/land/water etc, Self-combustion.

Exporting to Developing countries: Stoped foreign solid waste in 2018

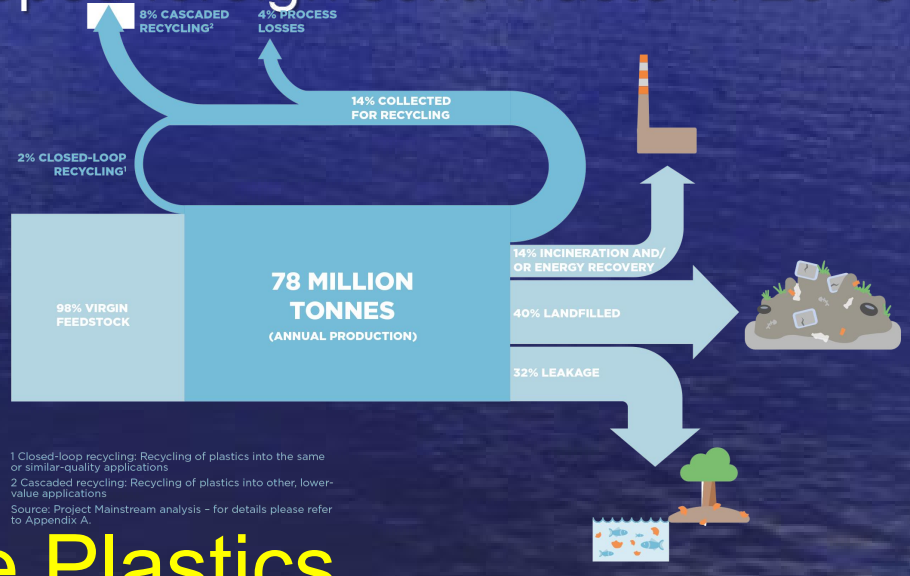
Reduce，Reuse，Recycle

8-9 billion tons plastics produced

only 10-30 % eliminated

> 6 billion tons waste remains

Impact environment for >100 yrs



UN & EU: Ban all Single Use Plastics

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EU Regulation: Ban all Single-Use Plastics

Council adopts ban on single-use plastics

Single-use plastics: New measures to reduce marine litter

Banning SUP including all Bio-Degradable Plastics: PBAT/PLA etc. even PHA

European Council
Council of the European Union

European Commission - Press release

Single-use plastics: New EU rules to reduce marine litter

A EUROPEAN STRATEGY
FOR PLASTICS
IN A CIRCULAR ECONOMY

https://ec.europa.eu/environment/waste/pdf/single-use_plastics

https://ec.europa.eu/environment/circular-economy/pdf/single-use_plastics_proposal.pdf

Europe is tackling the 10 most found plastic waste items

UK allows PE/PP + starch etc., which cause micro-plastics

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Old 3 R's + 3 New R's (Jem 2018/10 UN Asia HQ)

4th R: Replacement by BioPlastics/Materials whenever possible, especially for SUP

Bio-Materials: Starch, pulp, paper, cellulose, waste, etc for packaging...

Bio-based plastics: Reduce CO2 emission (vs fossil-based):

Non-degradable: Bio-PE, Bio-nylon, PEF (from FDCA)....

Degradable: PHA, PLA

Bio-degradable plastics: Degrade to water/CO2 in <3-6 mth / 2 yrs

Fossile-based: PBAT, PBST, PCL, some PBS. Same/high CO2 emission

Carbon-captured or semi-bio-based: PPC, PGA, some PBS

Bio-based: PHA (degradable in Nature), PLA (needs industrial composter)

Traditional plastics: Degrade in ~>100 yrs. Causing microplastics

PE, PP, PC, PVC, PET, PS, ABS, ... Serious long-term pollution problem.

PVA: Soluble & slowly degrade. Impact on aquatic lives

Dis-integration: PE/PP + starch, minerals, "enzymes", Oxo-catalysts, etc.

Bio-Plastics: small scale, expensive, weak

Healthy, Good for environment, Lower total costs, Need goverment protection/regulations

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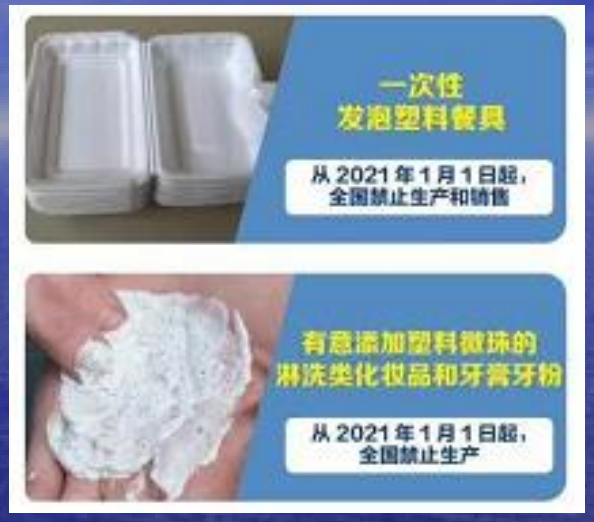
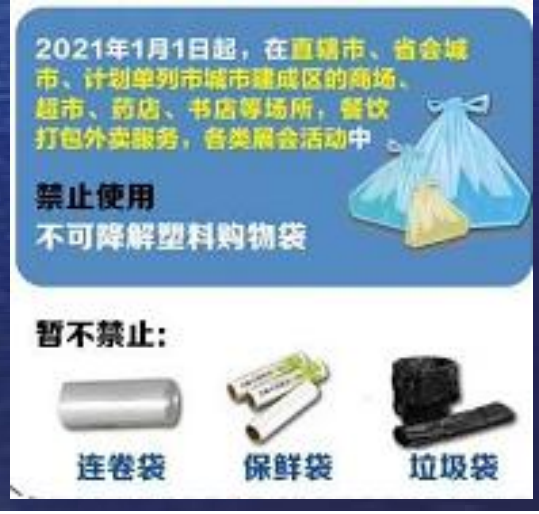
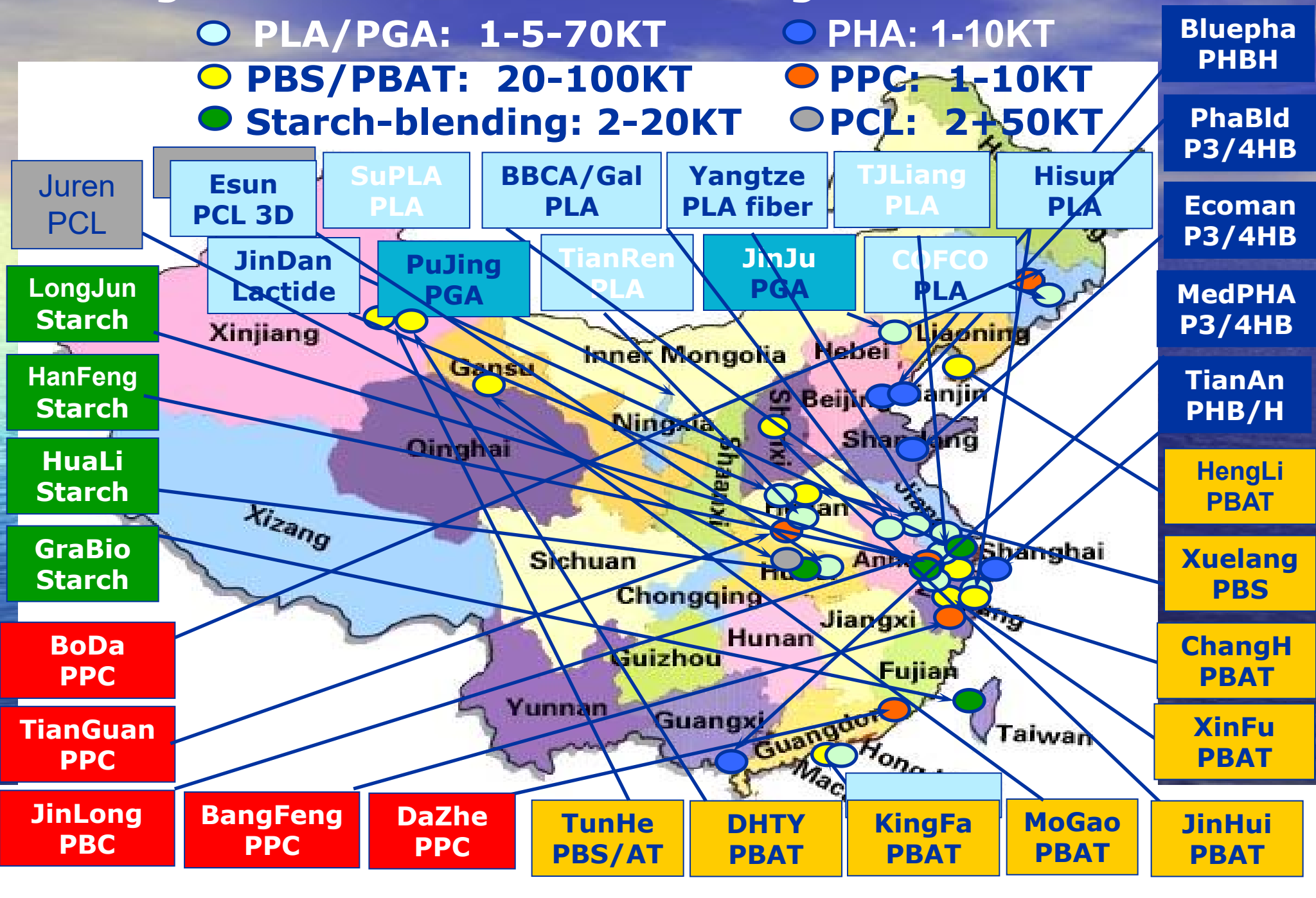
5th R: Regulation for BDP in China

Use only BDP for SUP by 2025 nation-wide. Forbit non-BDP





Major BioPlastics Projects in China



Key Bio-Plastics Projects

(& new PLA/PBAT plants)

2022/6: Current producers

PLA: NW 150 KT, TCP 75 KT

China: Hisun 45 KT, B&G 100 KT

PBAT: BASF & Novomont ~200 KT

China: > 300 KT, 6 major ones

DongHuaTY, Tunhe, Hengli

Jinhui, Kingfa, Changhong

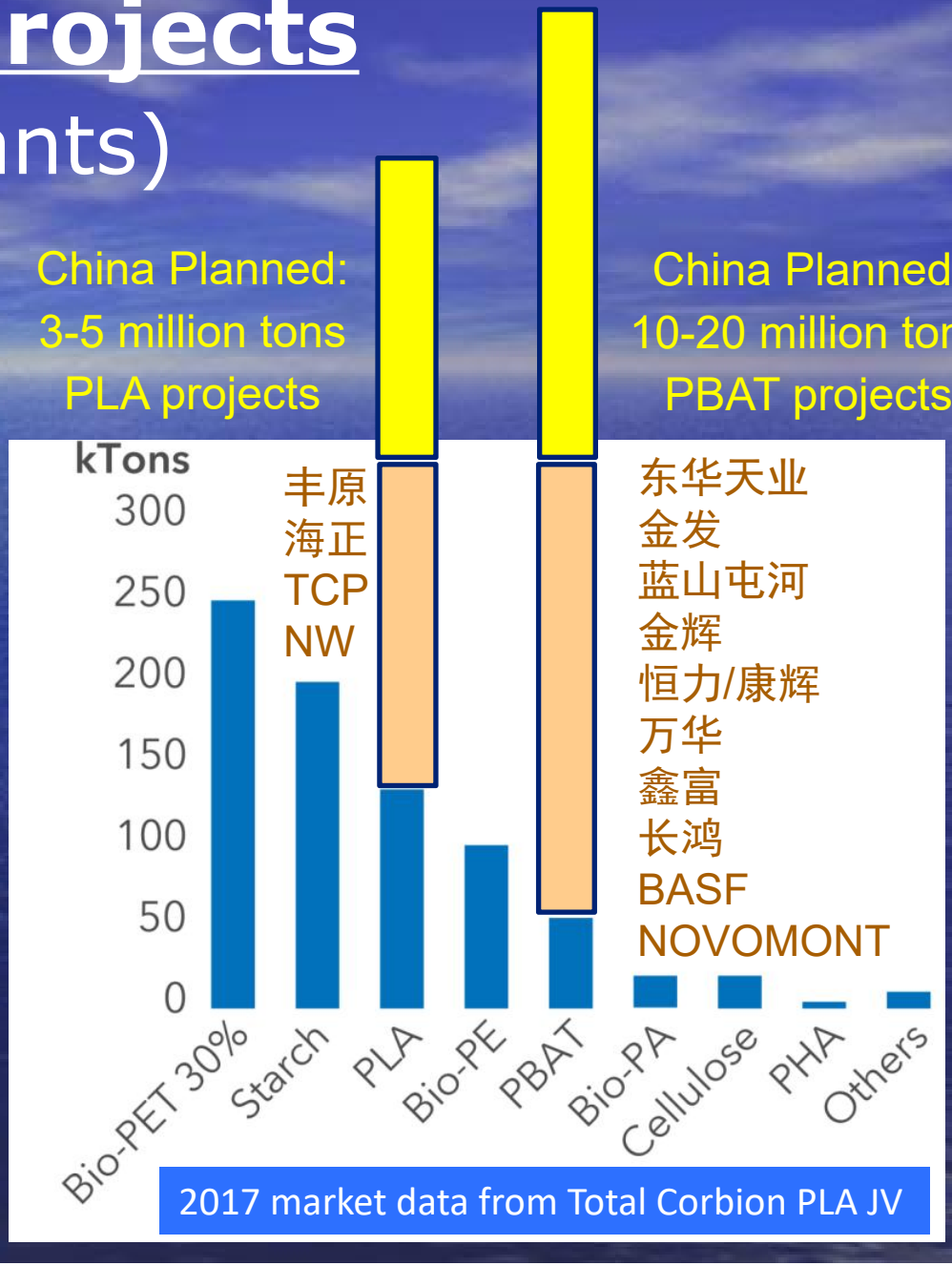
YE2025: Expecting > Mil T

PLA: NW+75, TCP+100, BBCA+300 KT

PBAT: China + >500 KT

Announced China project: 10-20 Mil T

(Many may not build/work)



PB-AT/ST/SA: flexible/soft fossile-based BDP

Mulch film, film bags (shopping, trash, shipping...)

3-5 MT market in China but planned 10-20 MT PBAT

Film bags: >2 MT Market (PBAT + 20-40% starch/minerals/PLA), Cost 2-3 X PE.

Mulch film: ~ 1 MT Market (PBAT with higher vaper permiability then PE)

Fit for wet area, root plants (peanuts, potatle) & small vegetable, short term. OK.

Not for cold/dry area, big plants (corn, tobacco, cotton...), 3-6 months needed

Other film: wrapping, shipping, bubble bags....

BASF：~70 KT + new JV plant in China

NOVOMONT: ~100 KT captive for film

China: 300-500 KT PBAT, Short of BDO

Tunhe, Jinhui, Kinfa, Hengli, Wanhua, ChHn.

+ ~50 new plants, ~20 MT announced

BDO projects catching up by 2025

Unrealistic over-planned.

Source：GuangHe, etc.

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PBS (Poly Butylene Succinate)

Property between PBAT & PLA
Small scale, niche market, expensive

Regular application similar to PBAT/PLA:
- film, coating, fiber..., 2x price, no clear benefits

Special/niche applications:
- Tableware, straw, etc. with higher HDT & fast processing
- Needs low residue level to meet food contact specs.

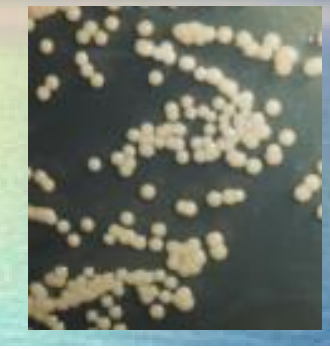
Bio-Succinic acid: multiple int'l companies
- China LangDian 20 KT

PBS: Thailand PTT-MCC 20 KT, bio-S
- China SeaLong 20 KT, fossil-S
- Tunhe uses PBAT lines for its PBS

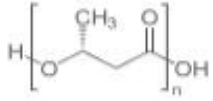
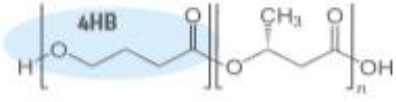
Source： HSM Tech, PTT-MCC, etc.

PHA group (e.g. PHB, PHBV...): all nature

fermentation process, bio-based, marine degradation
hard to reach high Mw/purity, low sugar yield, expensive...
(Some use solvent extraction process)



WW >50 projects: Daminer, Kaneka, CJ ... ~5 KT
(Shut-down: Metabolix/ADM.... up to 20 KT)
China: TianAn, MedPha, BluePha, PhaBuilder ...
(Idled: GreenBio, Ecomann, ... up to 10 KT)

PHA	P3HB (crystalline)	P4HB-3HB (semi-crystalline)	P4HB-3HB (Amorphous)
Structure			
4HB content	0%	5~15%	~50%
	Increase in 4HB content is associated with rubber-like property		
Features	·Brittle ·Tg = 2 °C	·General PHA ·Tg = - 10 °C	·Rubbery (Unique Property) ·Tg = - 30 °C

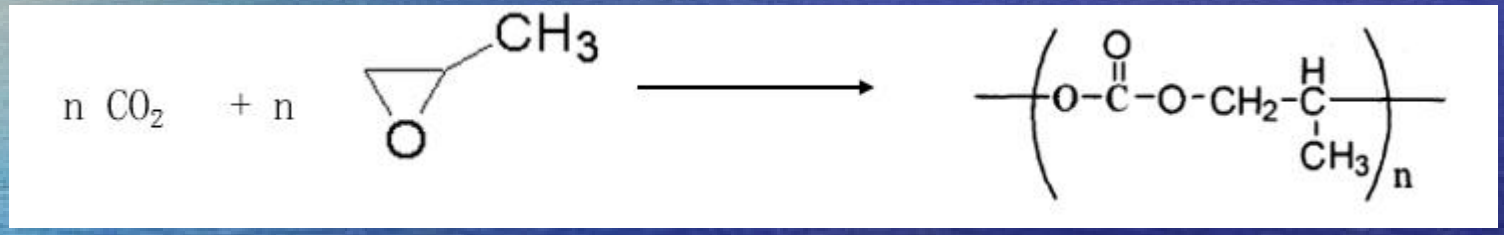
·Linear polyester produced by bacterial fermentation.

Parameter	Units	PHA resin types	
		Semi-Crystalline	Amorphous
Density	g/cc	1.23	1.23
Tg	°C	-10	-30.0
Tm	°C	119	N/A
Flexural Modulus	MPa	800	4
Hardness	Shore D	59 D	40 A
MFI	g/10 min	10	1
Charpy Impact	KJ/m²	5	N/A
Tensile Strength	MPa	36	1.5

Source： PHA Builder, BluePHA, etc.

PPC (Poly Propylene Carbonate): Carbon Capture
half bio-based, fast degradation, gas barrier...
(soft/weak, low HDT, special applications)

Fixing bio-CO2 from the off-gas of ethanol ferementation plants



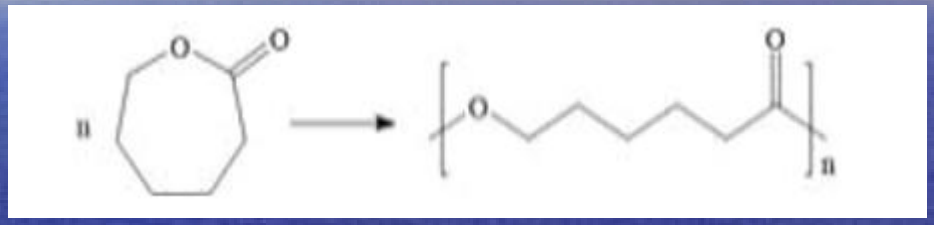
PPC：10-20 KT in China
5 plants (天冠博大中科金龙达志邦丰）

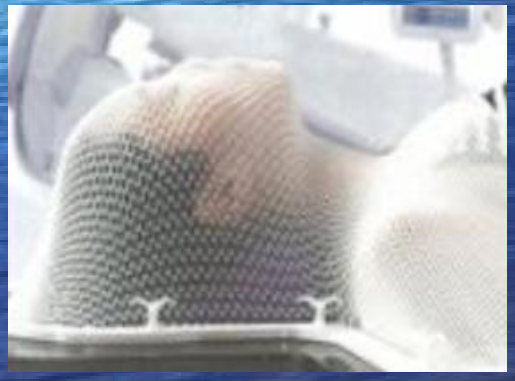
PPC-P：new version to improve strength
3 projects announced (联欣天源旭阳)

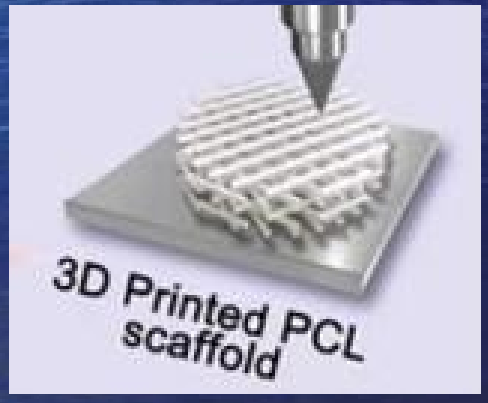
项目	指标
密度（g/cm³）	1.18-1.32
断裂拉伸强度（Mpa）	10
断裂伸长率（%）	200
缺口冲击（kJ/m²）	NB
维卡软化点（℃）	45-65

PCL (Poly Carprolactone)

fossil-based, expensive, soft, low Tm & HDT
special application, additive, polyol

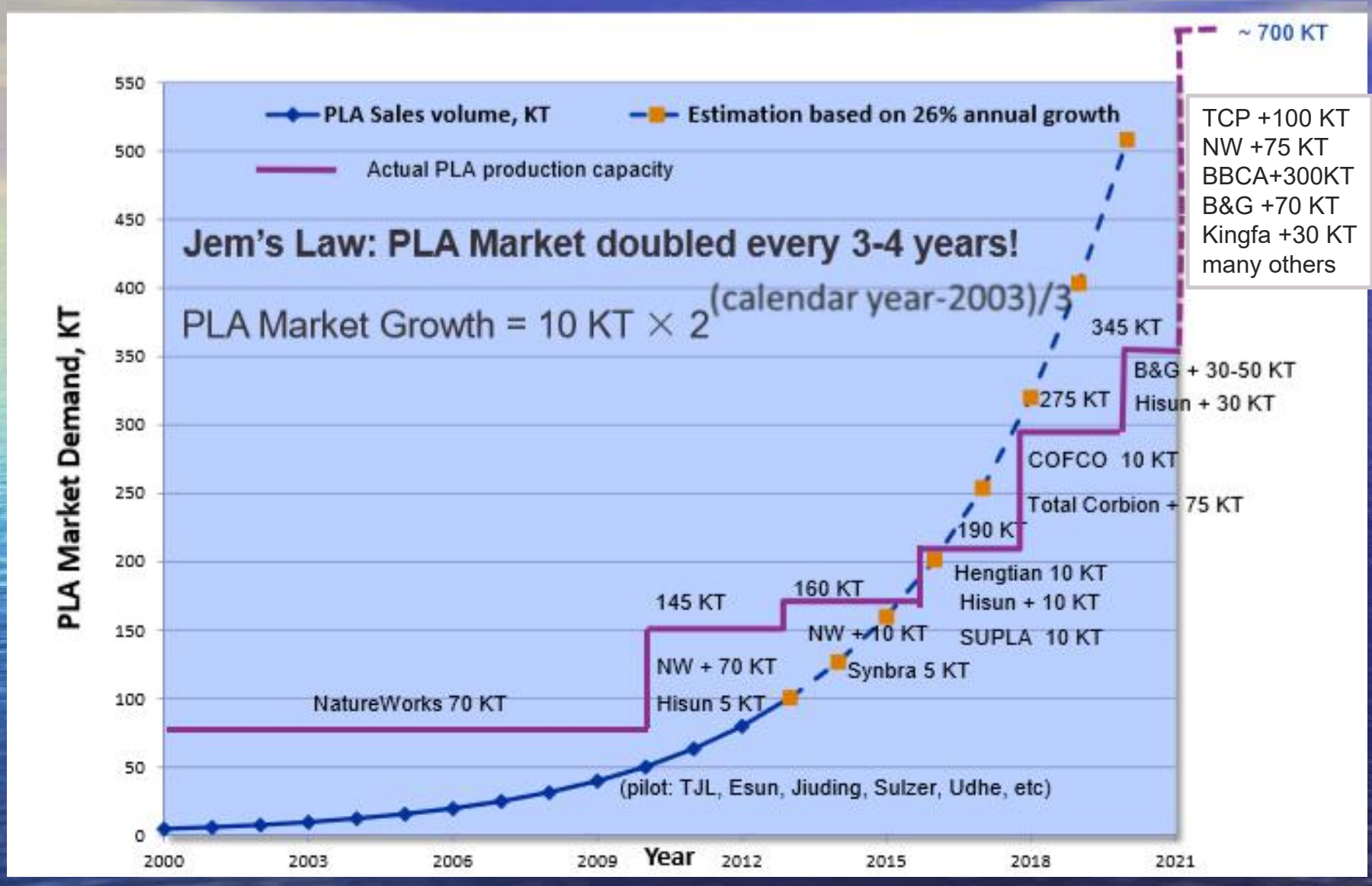




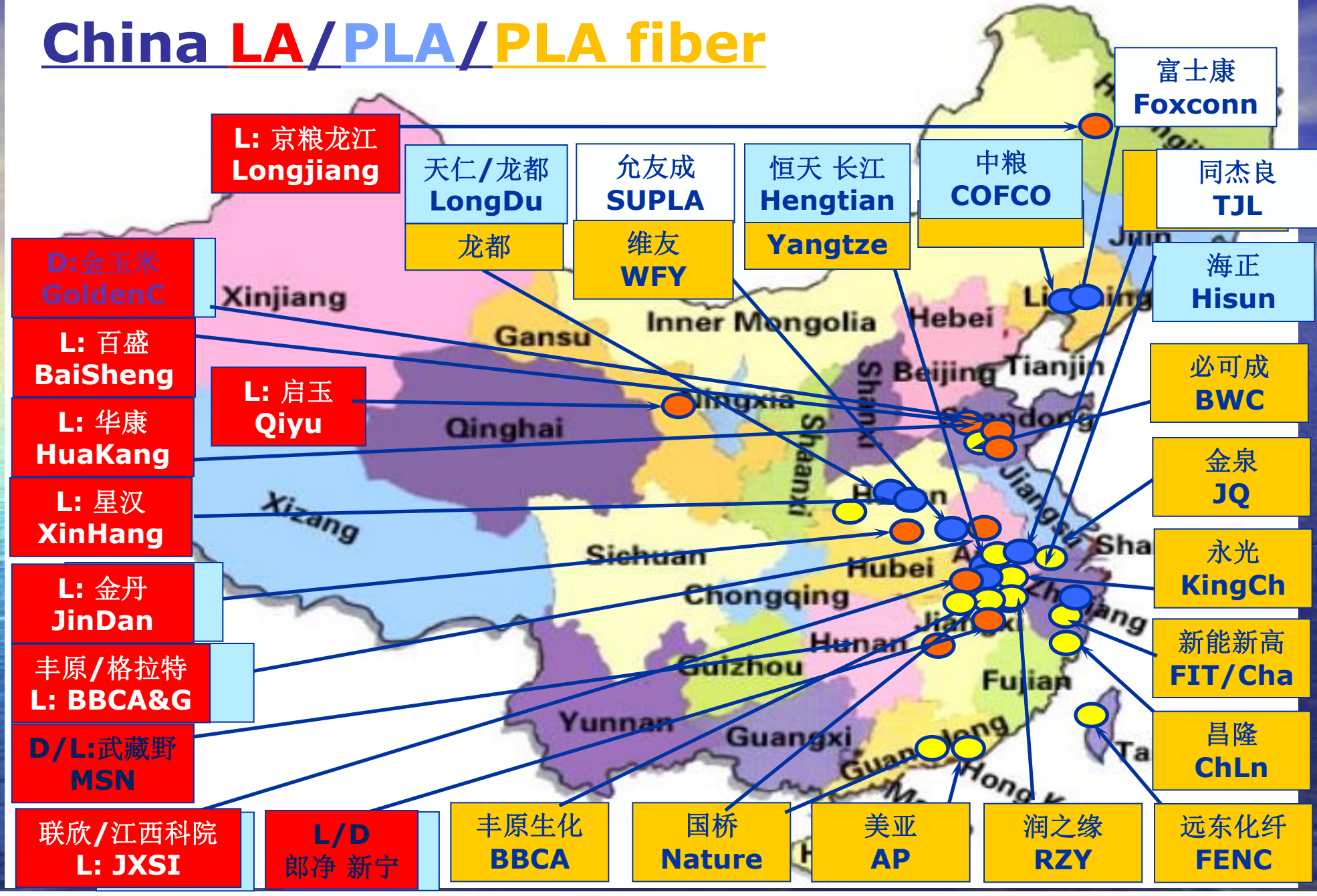


UK：40? KT Ingevity (Perstorp tech)
Japan: DAICEL 20 KT
China：BrightChina 2 KT, etc.
Juren 5 KT, + 50 KT due 2023/7

Jem's Law（2012）： PLA Demand Forecast



China LA/PLA/PLA fiber



PLA food/drink applications in China

cutteries, straws, bowls, cups, boxes, coffee capsule...
hot, cold/r.t., dispossible or semi-durable
(PLA products need industrial composters!)








Source： HSM, Huizefeng, XinYiFeng, Hisun, GuangHe, P&P, etc.

PLA high-end/value applications in China

bottle, sand pipe, tea bag, 3 C, glases, filter, card...
(need at least 3 years shelf-life or durability)

Need 3-5 yrs durability

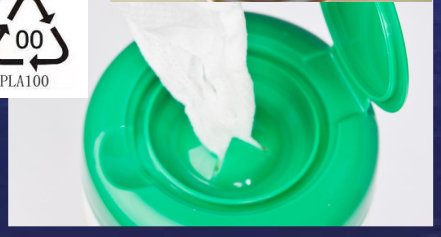
Source： Naton, Hengtian, Shikaer, Jierong, etc.

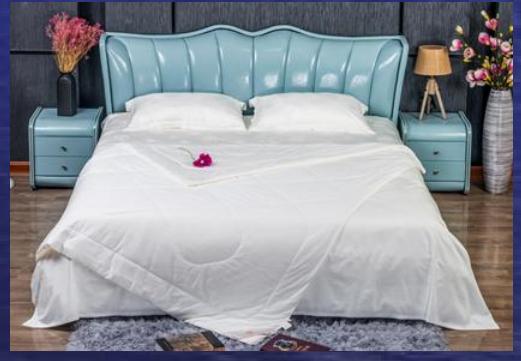
PLA fiber applications in China

shirt, tie, underwear, mask, wet-wipe, filler, pillow, blanket...

staple, filament, nonwoven (melt-blow, thermo-bond, skin-core...)

PLA 3-layer Non-woven
static ele. charged. No PP
Meet N90 or N95 standards
Bio-degrable/FDA certified





Source： BBCA, NatureArts, Hengtian, RenYi, Yongguang LightBatt/Gaoxin,

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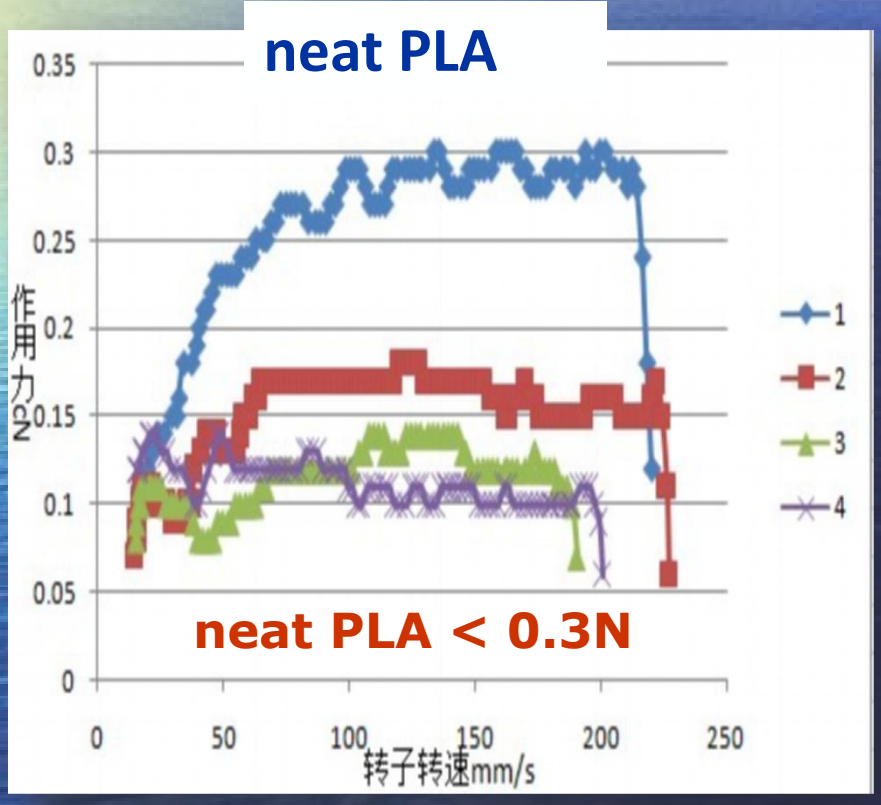
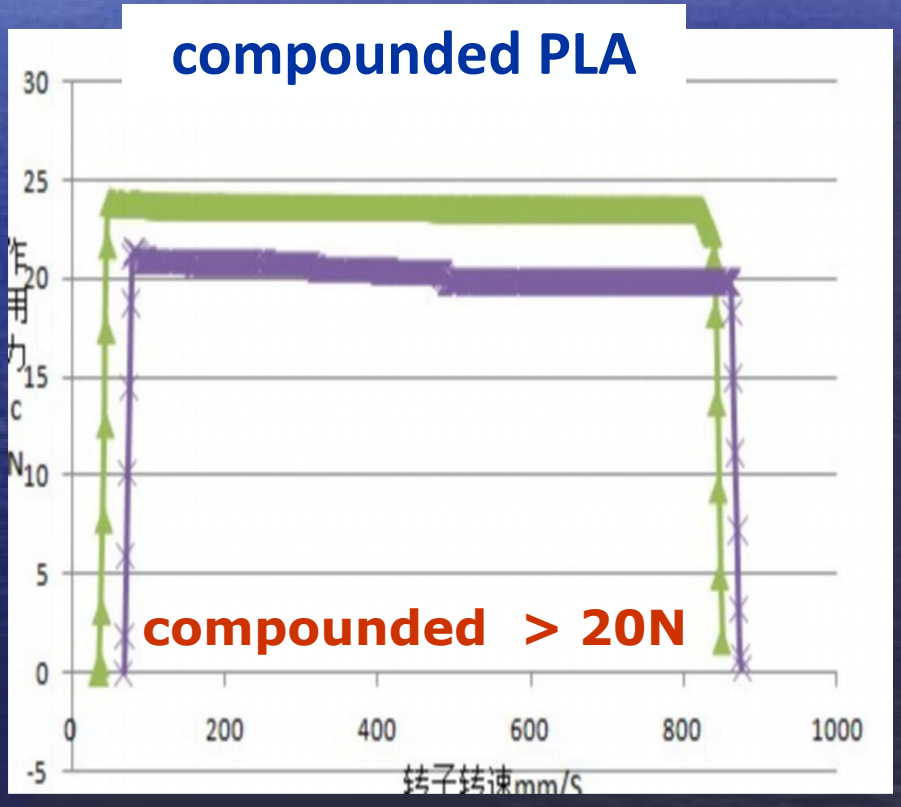
6th R: Research & Innovation

to improve the property/cost ratio

Compounding to increase melt-strength 70 folds
(needed for PLA foaming ratio 10-20X)





Source： CAS Ninbo Institute of Tech

PLA/PBAT Foaming Products

sport goods, holding box, heat resistent lunch box...
(PLA rigid, PBAT soft)







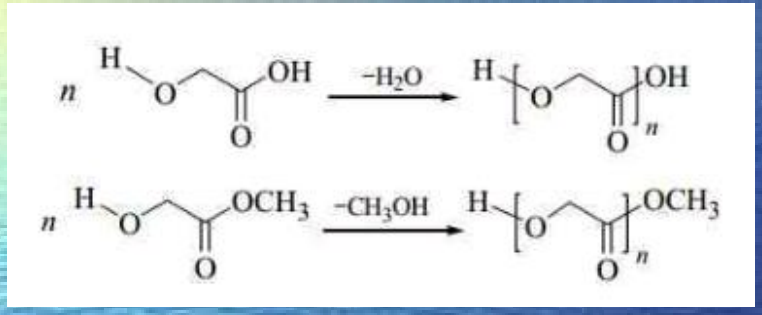


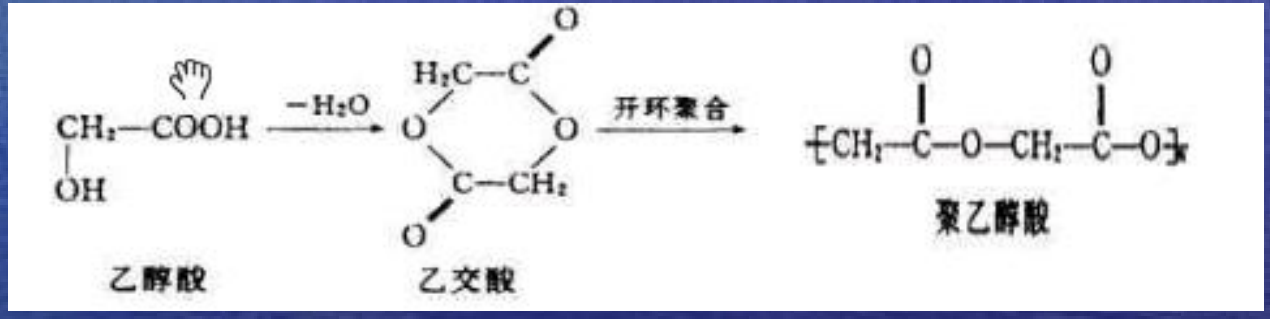
Source： Bio-Plus, Tongjia

PGA (Poly Glycolic Acid)： Carbon Capture

Fixing CO (or CO2), off-gas from coal related plants （China： very rich on coal but not oil/gas）

Process: from CO to DMO (Dimethyl Oxalate), GA and/or Glycolide then PGA





Kureha：4 KT in USA
China Pilot：0.5, 1.5, 3 KT
ChnEnergy: 50 KT 8/2022
SinoPec: 200 KT by 2024
Phase 2 +300 KT

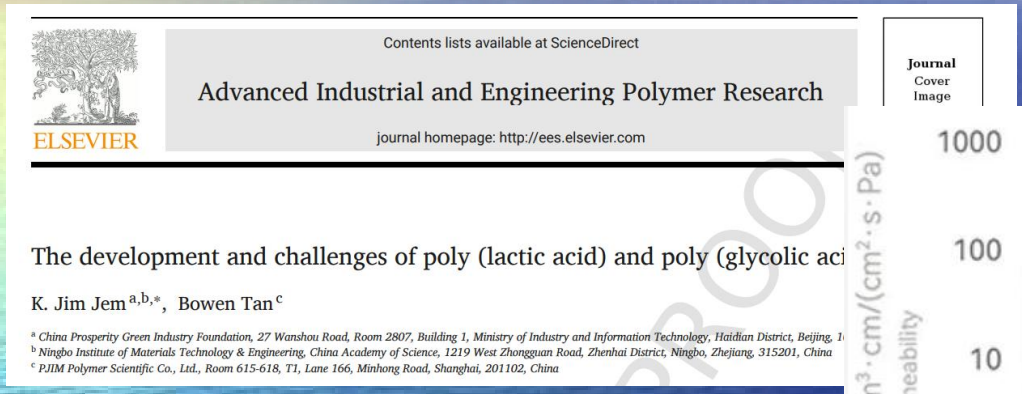
Basic characteristics of PLA, PGA and other traditional plastics.

	Tg (°C)	Tm (°C)	Tensile strength (MPa)	Yong's modulus (GPa)	Elongation at break (%)	Flexural strength (MPa)	Flexural
PLA [12]	57–58	140–180	53	2.4	5	92	3.4
PGA [41]	35–40	220–230	115	7	16.4	222	7.8
PBAT [42]	−30	110–120	20	0.08	> 900	3.1	0.08
PCL [43–45]	−60	60	14.6	0.4	600–900	23.4	0.6
PET [46–48]	69	255	47	3.5	2–83	118	4
PP [12,49]	−20	175	31	1.5–2	80–350	40	1.5
PS [12,50]	85	105–110	45	3–3.5	4	70	2.5
PA 6 [51]	60	220	56–90	2	70	77.2	1.3

Source： Pujing (PGA tech provider)

PGA vs. PLA : Similar/Complementary

Strong/rigid, high HDT, fast degradation, gas barrier, soon cheaper
(Shortage: high density, darker & not durable but resolvable)



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The development and challenges of poly (lactic acid) and poly (glycolic aci

K. Jim Jem [a,b,*], Bowen Tan [c]

[a] China Prosperity Green Industry Foundation, 27 Wanshou Road, Room 2807, Building 1, Ministry of Industry and Information Technology, Haidian District, Beijing, 1
[b] Ningbo Institute of Materials Technology & Engineering, China Academy of Science, 1219 West Zhongguan Road, Zhenhai District, Ningbo, Zhejiang, 315201, China
[c] PJIM Polymer Scientific Co., Ltd., Room 615-618, T1, Lane 166, Minhong Road, Shanghai, 201102, China

PROOF

PGA will replace some PLA applicaitons

MARINE OK bio-degradable TÜV AUSTRIA MARINE

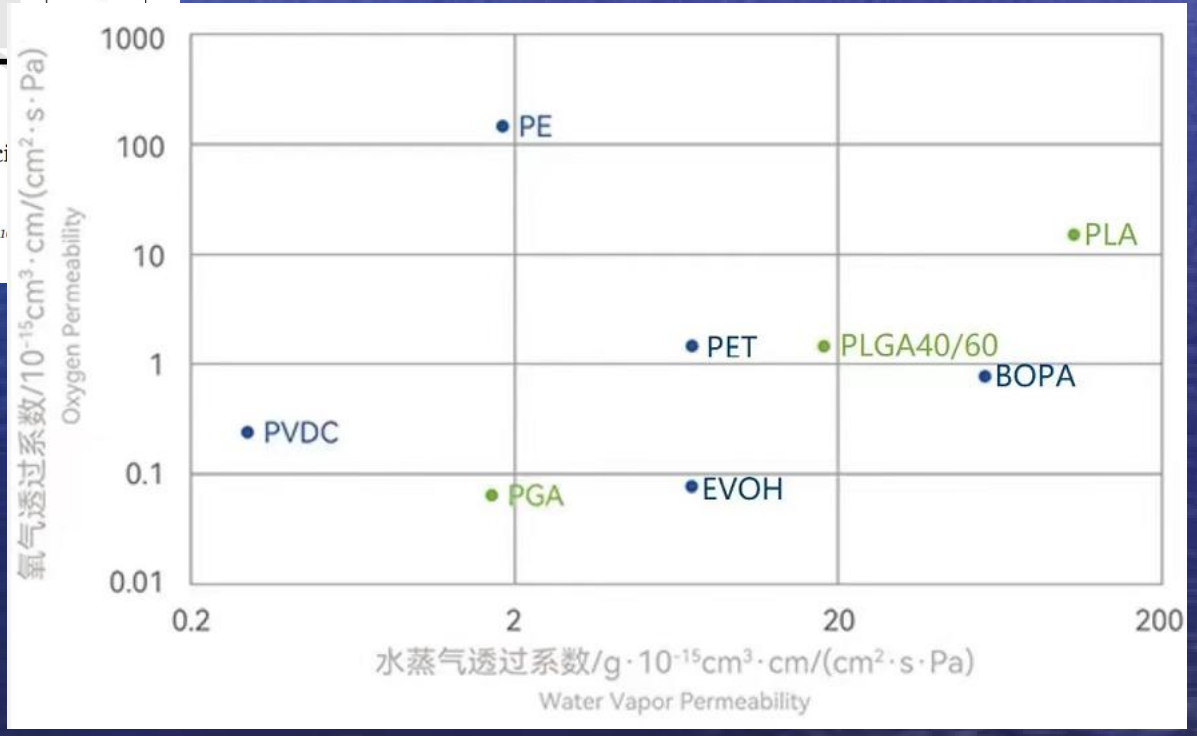
TÜV AUSTRIA

CERTIFICATE FOR AWARDING AND USE OF THE
'OK BIODEGRADABLE MARINE' CONFORMITY MARK

TA8062004767

Issued by TÜV AUSTRIA CERT GMBH

Product(s):	
Domain	Products Biodegradable in SEAWATER
Group	Raw material
Family	Bio material
Type	In form of Resin or Granulates
Trade mark	PGA



"Marine bio-degradable"

Source：Pujing Chem

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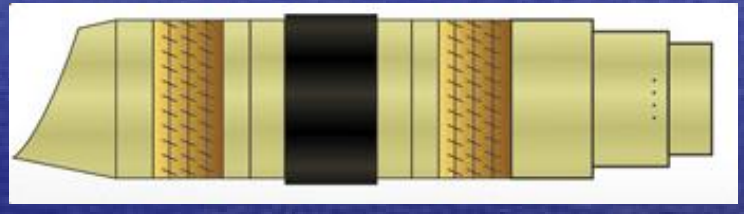
PGA Applications in China

tableware, straw, bags, hotel SUP, oil-gas drilling...
(future cost only half of PLA, no sugar needed)
Fit China's needs of using coal & reduce CO2 & plastic pollution

Oil-gas drilling: High HTD
High strength, Fast digradation



proprietary design not to be shown

Source：Pujing, Xinyifeng, Sunflux...

Paper/Pulp Applications in China

tableware, cuttery, cup, bowl, egg box, lunch box, ...
(paper bottles need interanl plastic layer)

Steam/energy intensive. Need water-prof coating/layer

paper board w/ BDP coating layer

Source: Hengxin, Zidan, HuiZeFeng...

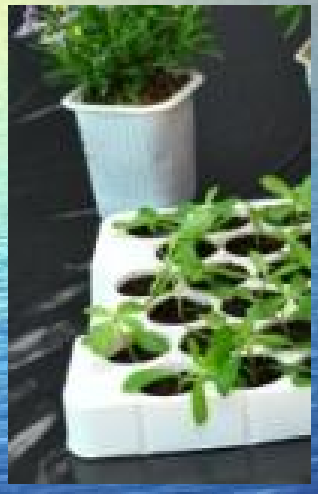
PBS frame, w/ cover：46.4g

PLA film on top 28.4g

Starch Applications in China

foaming, compounding, additing to BDP or PE/PP bag, film, tray, filler, ...

BDP：Starch+PBAT etc



20-30% Starch
+ PLA or PBAT
for rigid/soft BDP
fast/control degradation

Source：GraBio, Green Fill, ...

Starch, modified/foamed

Fake BDP：Starch+PE etc

Fakely claimed:
"All-nature, Degradable"
PE portion breakdown
to micro-plastic particles
causing serious pollution

CNITECH

GFHS

Future Work for BDP in China: #1

Build Composting/Biogas Facility (esp. for PLA ...)

for Circular Economy & Sustainable Development

Incineration: Force BDP and gabage seperation, then dump all waste to inceneration, add fuel to raise temp, cause CO2 emission, defeat the whole environment protecion program. Wrong direction.

Composting/Biogas Plants: Use localize or subcontract small fast-track industrial composters to reduce volume of wet gabage, then ship to central final maturalizing facility. Carbon neutral.

Future Work for BDP in China: #2

Law Enforcement to stop Fake BDP

e.g. oxo-degradation & starch/additives to PE/PP... banned in EU, illegal in US

Central goverment banned traditional non-degradable plastics (PE, PP etc) for SUP, and only allow "Degradable" SUP for personal needs.

附件：公共机构停止使用不可降解一次性塑料制品名录（第一批）名录确定：含聚乙烯（PE）、聚丙烯（PP）、聚苯乙烯(PS)、聚氯乙烯(PVC)、乙烯-醋酸乙烯（EVA）、聚对苯二甲酸乙二醇酯（PET）等非生物降解高分子材料。

Soon expand to hotel & agri SUP, etc.

Problem: Some local companies claimed thier PE+starch/additives products (e.g. "OBE") as "Degradable", and called PLA/PBAT etc as "Bio-Degradable" to confuse local goverments. Even called me a spy.

Future Work for BioPIs in China: #3

Solid RD to improve tech & reduce costs
(especially for lactide and compouding)

- Most BDP: technology and cost competitive (barely)
  Will compete by big volume/scale. Need effort/control.
- Bio-based, non-degradable plastics: bio-PE, PEF, nylon...
  Start to compete with other countries. Not there yet.
- Bio-waste (cellulose) conversion to sugar for fermentation:
  Cost > corn sugar, similar to other countries. Far to go.
- LA/lactide/PLA: Lower on conversion yield & purity.
  PLA cost >50% higher. High-end PLA worse.
  Many fake projects will fail/delay. Need solid effort.
- Coumpounding for the needs, e.g. cost, mulch film, bottle...

BioPlastics for our Cleaner Earth

Summary + Q&A

- **Current China**: Largest CO2 and plastics producing country, but not per capita (US #1 polluter?). Very serious to reduce pollution, protect environment, promote BioPlastics/Materials. Falling Behind!
  (vs. EU/Canada bans BDP for SUP, UK allows PE/PP+starch, US?)
- **Future China**: Soon to be the largest BDP producer (especially PBAT/PLA) and market (>5 mil T) in the world. Set the example!
  Work to do: Add composting facility. Stop fake BDP, Improve tech & reduce costs, Enlarge the BDP/SUP market, control over-expansion.
- **One Earth**: Global collaboration & Harmonization of BDP/SUP policy.

K. Jim Jem, Ph.D., P.E.
Jim_Jem@126.com, +86 13661595602