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Bio-plastics market assessment

Final Report

Milan, June 23rd, 2014

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Executive summary (1/2)

- **Plastics** industry is a **growing market** (2010-13 CAGR of 4%), worth tons 300mln globally, and with conventional representing still 99% of total, **driven by performance**, with Automotive outperforming other segments of applications (+6% CAGR) and medical uses rapidly gaining pace
- **Bio-plastics** has still a **marginal share** (1% of total market) but **market dynamics** are **raising** the **expectations for a** widespread in the next future:
  - **Customers** are increasingly **demanding for 'green' products**, demonstrated by recent multinationals initiatives
  - **Regulators** are constantly **raising the bar** in terms of gas emissions and – in certain countries – some **clear directive** already exists aiming at **replacing conventional plastics** with bio-products
  - **Plastic producers** are **seeking** for **feedstock diversification**, to reduce dependency from crude oil and hedge against future price uncertainty
- **Two different families of products** characterize today's Bio-plastics market:
  - **Bio-based plastics** show **performances similar to their conventional counterpart**, with little-to-no increase in cost of production and minimal impact on value chain. **However**, they are not 100% Biodegradable and **their environmental impact** - although reduced – is **not entirely eliminated**
  - **100% Bio-products show** very **diverse performances**, with **PHA outperforming the others** and potentially applicable on an array of end uses – **production costs** are **still not competitive with conventional plastics** (currently **no economies of scale** and low productivity) and **complexity** of production **impacts value chain**

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Source: A.T. Kearney analysis

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Executive summary (2/2)

- **Overall Bio-plastics** market is expected to **hit 9Mln tons in 2020**, in the short term **driven by bio-based** products ready availability and competitiveness; **100% Bio-products are pushing penetration from 2017 onward**, when production costs are expected to lower
- **PHA** share is **expected to hit 400k tons in 2020** (26% of total 100% bio-products) driven by:
  - Expected **reduction on cost of production**, thanks to enhanced yields and utilization of cheaper feedstock (e.g. sugar molasses)
  - High **fit with bio-medical applications**, thanks to PHA complete bio-degradability and natural origin
  - **High level of substitution on technical applications** (e.g. automotive and electronics) where high performing / functional plastics are required and **prices are premium**

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Source: A.T. Kearney analysis

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Agenda

- **Project objectives and approach**
- Current plastics industry overview
- Bio-plastics market growth assessment
- Evaluation of Bio-On PHA applications potential

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Objective of the study is to assess the market potential of bio-plastics with particular focus on PHAs

Project objectives and deliverables

Bio-plastics (PHA) applications market assessment

Objectives

- Critical view on **overall plastic market scenario and dynamics**
- Evaluation of **bio-plastics** (focus on PHA) **market**
- Identification of **PHA end-market applications** potential

Deliverables

- Mapping of **conventional and bio-plastics industry** (demand, capacity, prices)
- Assessment of **internal and external trends** impacting bio-plastics penetration (regulatory, sustainability, costs…)
- Evaluation of bio-plastics **value chain** structure and key **players dynamics**
- **Level of confidence** on bio-plastics market value projections
- Identification and evaluation of **PHAs** potential **applications** by segment
- Estimate of **substitution trends by segment** based on key drivers

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Source: A.T. Kearney project proposal

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Approach has been structured along 3 macro-activities

Project approach

Kick-off of the activities

Mapping of current market

Key drivers for shift and value chain assessment

Degree of substitution evaluation

Activities

- Bio-on business comprehension
- Mapping of conventional and bio-plastics market, split by
  - Polymer (e.g. PE, PHA, etc.)
  - Segment (e.g. pharma, automotive, packaging, etc.)
  - Geography
- Prices trend by material

- Identification of main drivers for conventional plastics substitution
  - Internal (e.g. performance increase)
  - External (e.g. increase in petrol price)
- Analysis of plastics/bio-plastics value chain structure and key players

- Mapping of potential market segments for PHA
- Identification of addressable markets
- Estimate of degree of substitution by segment

Methodology

- Interviews with Bio-on management
- Desk analysis
  - ATK internal sources
  - Bio-on sources

- Interviews with Bio-on management
- Desk analyses on Bio-on datasheets / documentation
- External interviews with experts

- Interviews with Bio-on management
- Interviews with market segment experts
- Desk analyses

Continuous interaction with Bio-on top management to review outcome

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Source: A.T. Kearney

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Industry specific data sources have been used, integrated with interviews with Bio-On management and external experts

Bio-plastics market assessment: sources

Data sources	Interviews
☑ **European Bioplastics** - Institute for bioplastics and biocomposites (2012)	☑ Bio-On President and CEO: Marco Astorri
☑ **Profound** - Biopolymers/Bioplastics market (2014)	☑ Bio-On COO: Vittorio Folla
☑ **Technavio** - Global bioplastics market (2011)	☑ Bio-On Vice President & CFO: Guy Cicognani
☑ **Morgan Stanley** - Chemicals is green (2012)	☑ Interview with A.T. Kearney contacts among EPI practice experts in Plastics/Bio-plastics
<u>Other specialized reports on market trends:</u> ☑ **ICIS** - World polymers outlook (2014) ☑ **Plastice** - Future of bioplastics (2013) ☑ **Nova Institute** - Bio-based polymers (2013) ☑ **OECD** - Policies for bioplastics (2013) ☑ **Jefferies** - Bioplastics (2013)	
<u>Other key data sources:</u> ☑ **Factiva** ☑ **Bloomberg** ☑ **WorldBank** ☑ **Companies' official annual reports**	
<u>Press search and additional sources:</u> ☑ **Nova Institute press releases** ☑ **Chemsystems** ☑ **Institute for bioplastics and biocomposites**	

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- Project objectives and approach
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  - **Mapping of industry segments and applications**
  - Volumes and prices trend
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Plastics industry is massively present in most important industries, spanning from low end to more advanced applications

Plastics categories of application

Level of complexity

Packaging

Bottles: Injection stretched and extrusion blow moulded bottles
Food & beverages: general plastic containers for food and beverages
Shopper: shopping bags
Other: other plastic containers (e.g. Detergents)

Consumer products

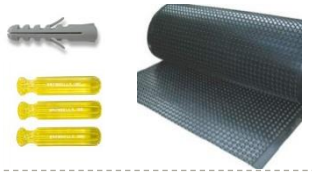
Office supply and furniture: writing supplies, correction rollers, chairs, etc.
Household products: bathroom supplies, cosmetics, hygiene, straws, etc.
Other: toys, sports & leisure, tableware, etc.

Agricultural applications

Horticulture & Agriculture plastics equipment: agricultural films and liners, dispenser plant pots, etc.

Building and Construction

Building and Construction plastics equipment: tool handles, plugs, insulates, terrace surfaces, carpets,



Advanced applications

Consumer electronics: casing for computers, mice, keyboards, phones, mobile phones, cable insulation, etc.
Automotive: hoses, foams, foot mats, airbag covers, etc.
Pharma & Medical equipment: implants, bone screws, tablet capsules, etc.

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Source: European Bioplastics, A.T. Kearney analysis

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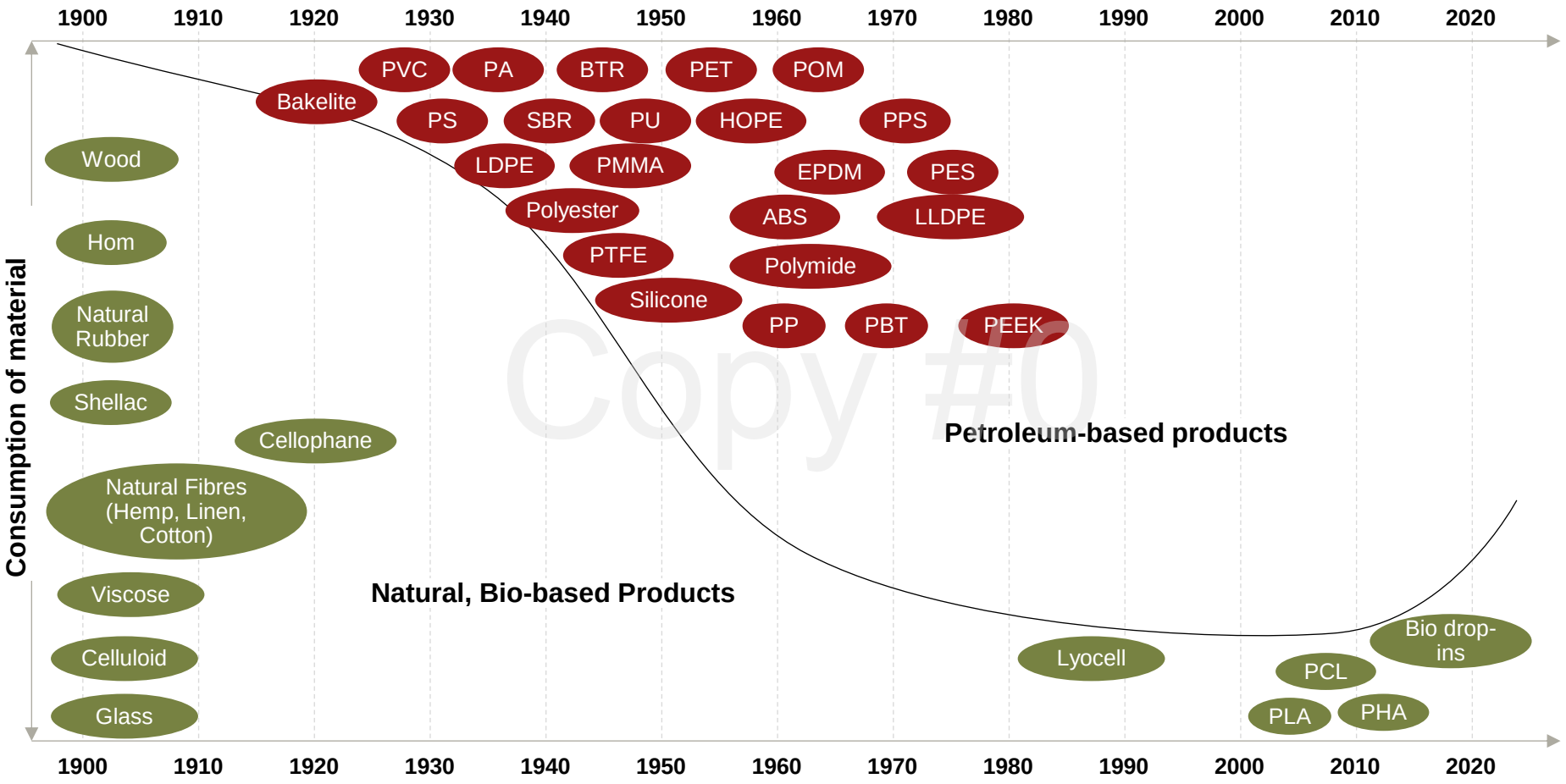
After accelerating in 1950s, shift from Bio to Petroleum-based products is beginning now to reverse

Natural products and petroleum-based products consumption trend

Illustrative



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Source: Morgan Stanley, A.T. Kearney analysis

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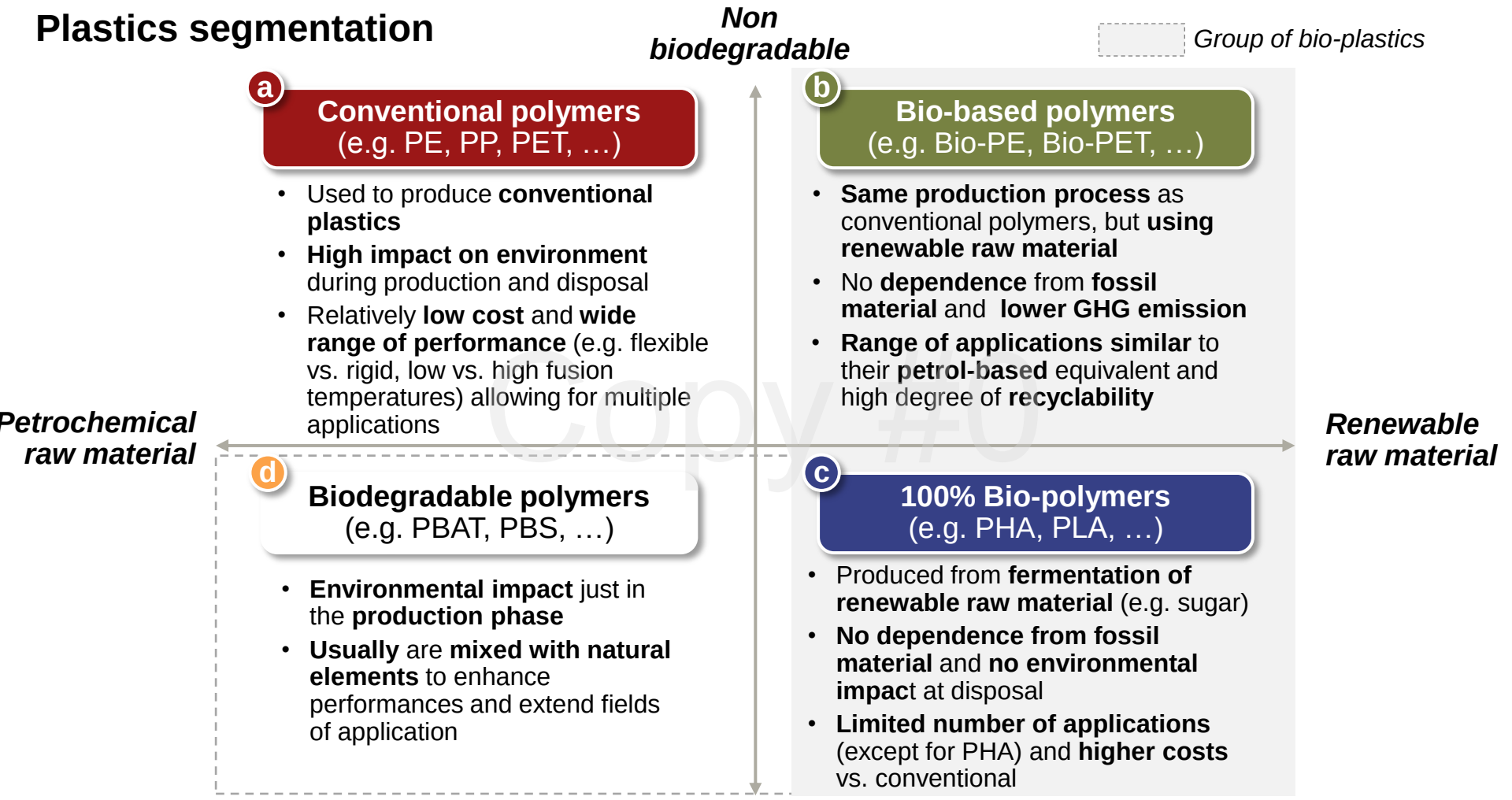
Four main segments of polymers/biopolymers can be identified based on the degree of biodegradability and type of raw materials

Plastics segmentation



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Source: European Bioplastics, A.T. Kearney analysis

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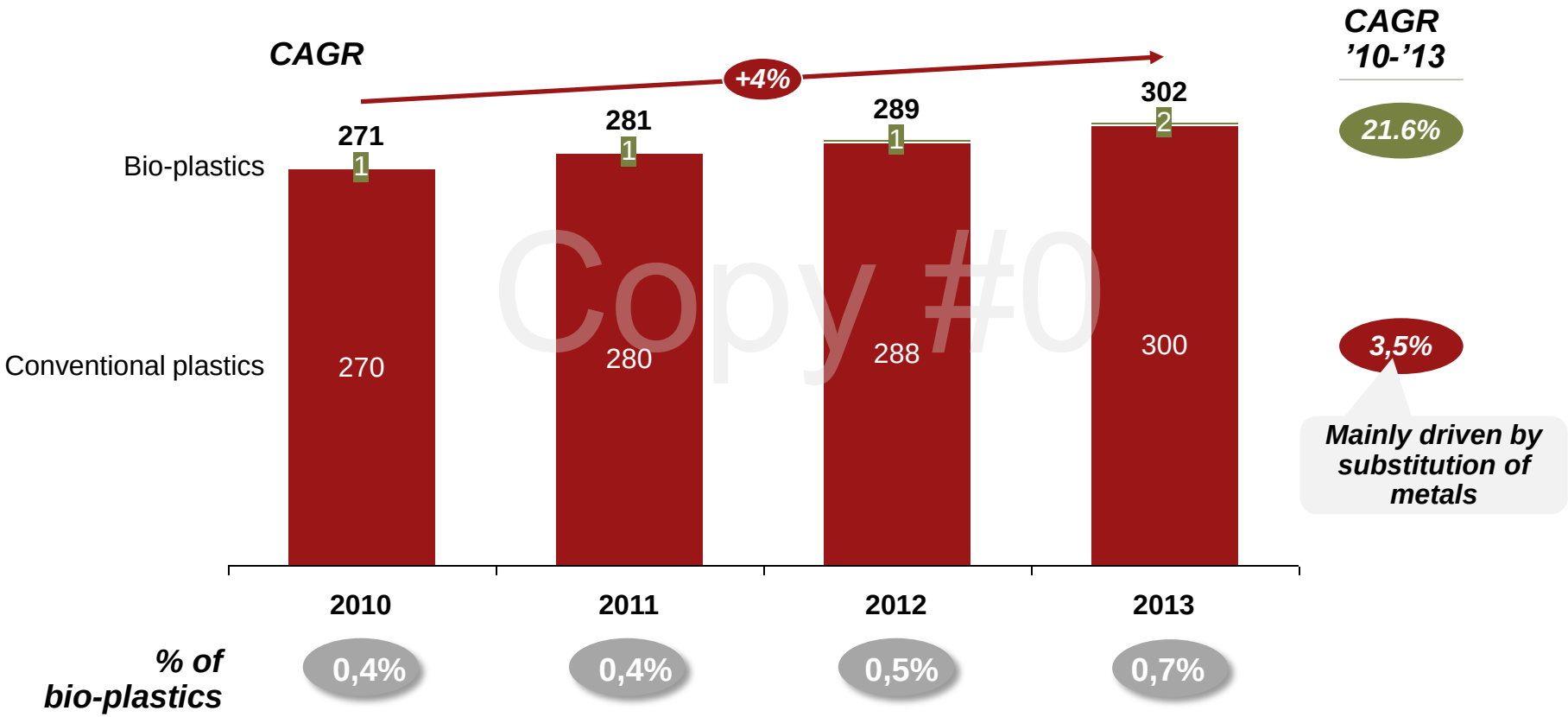
Plastic demand has peaked at 300mln tons, with conventional still at 99% of total and bio-plastics showing double digit growth

Global plastics production – Conventional vs. bio (Mln tons)



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Source: Plastics Europe, European Bioplastics, A.T. Kearney analysis

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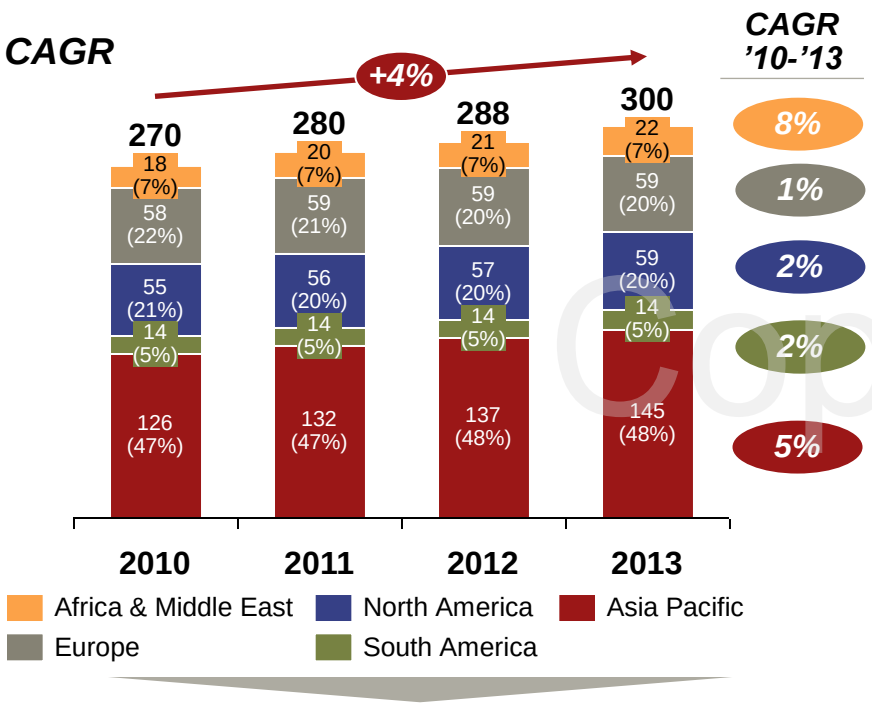
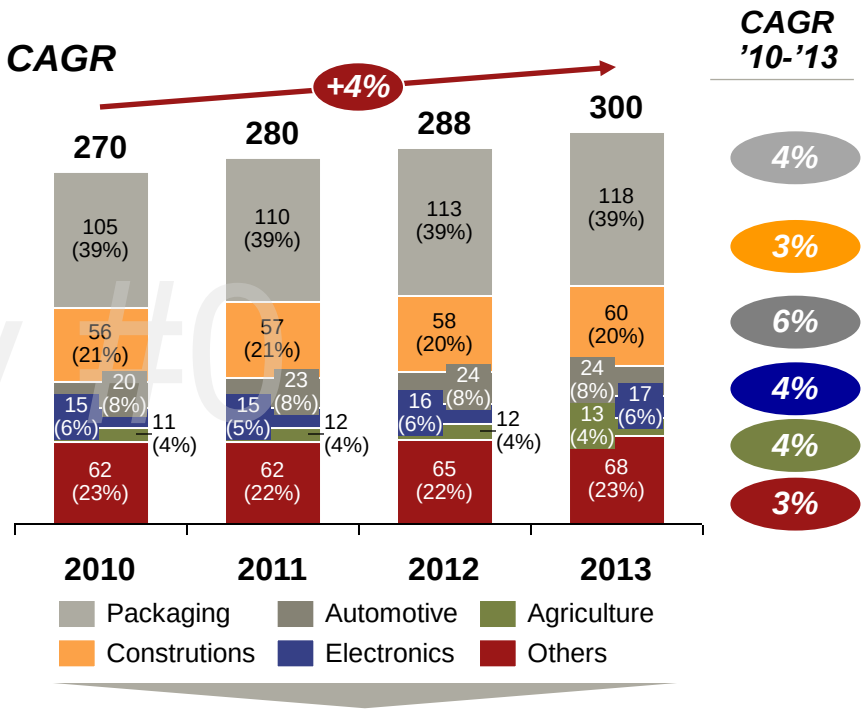
Global plastic production is growing mostly in Asia Pacific, with Automotive outperforming other segments of applications

Global plastics production – split by region and end use (Mln tons)

Split by region



Split by end use



Plastic production mostly **driven** by **Asia Pacific due** high **demand** and **low** production **costs**, **Europe flat** since 2011

Packaging and **construction** account for **~60%** of total, **Automotive** enjoys **highest growth** driven by sought for lightness

Source: Plastics Europe, A.T. Kearney analysis

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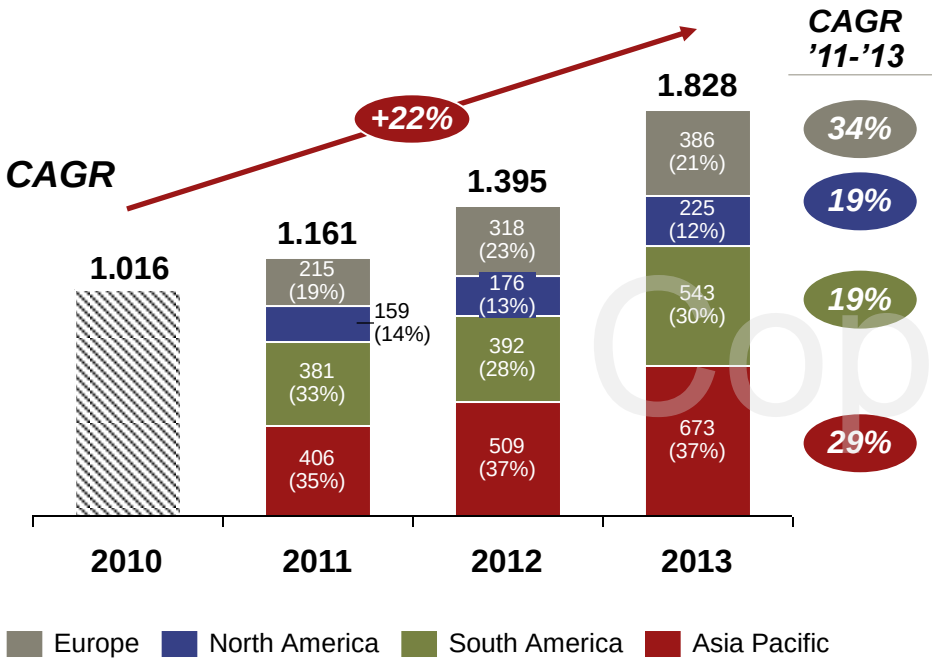
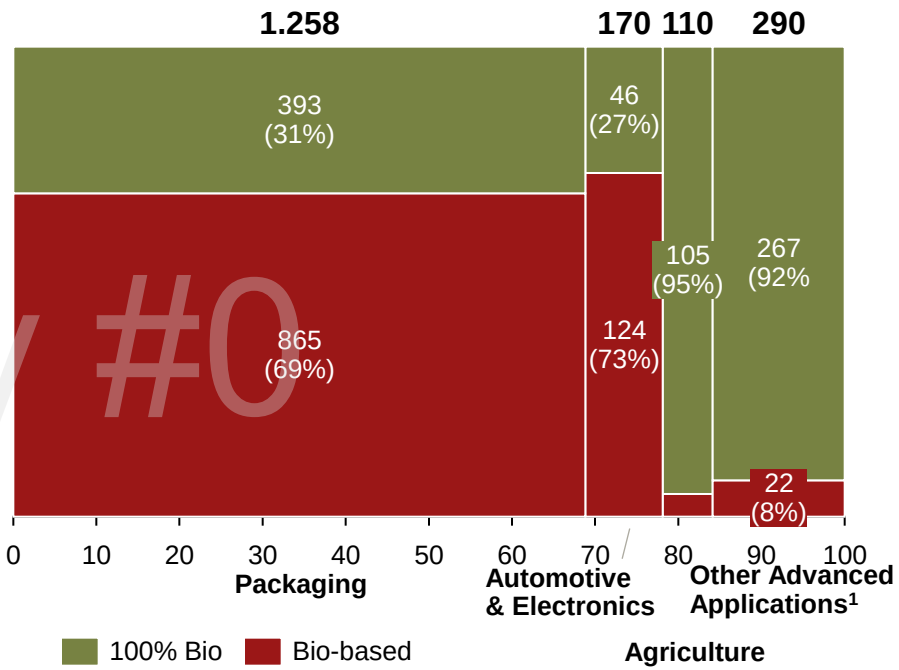
Bio-plastics are growing mostly in Europe and Asia, with 100% biodegradable polymers focused on high-value applications

Global plastics production – split by region and end use (‘000 tons)

Split by region



Split by end use and bio-plastic segment



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Bio-plastics production **growth** is **driven by Europe** due to high **dependency on naphtha** as feedstock

Bio-based is mostly used for **Packaging**, accounting for ~70% of total, **100% bio covers agriculture** and **advanced applications**

1 Includes construction, pharma and medical equipment and other
Source: Plastics Europe, A.T. Kearney analysis

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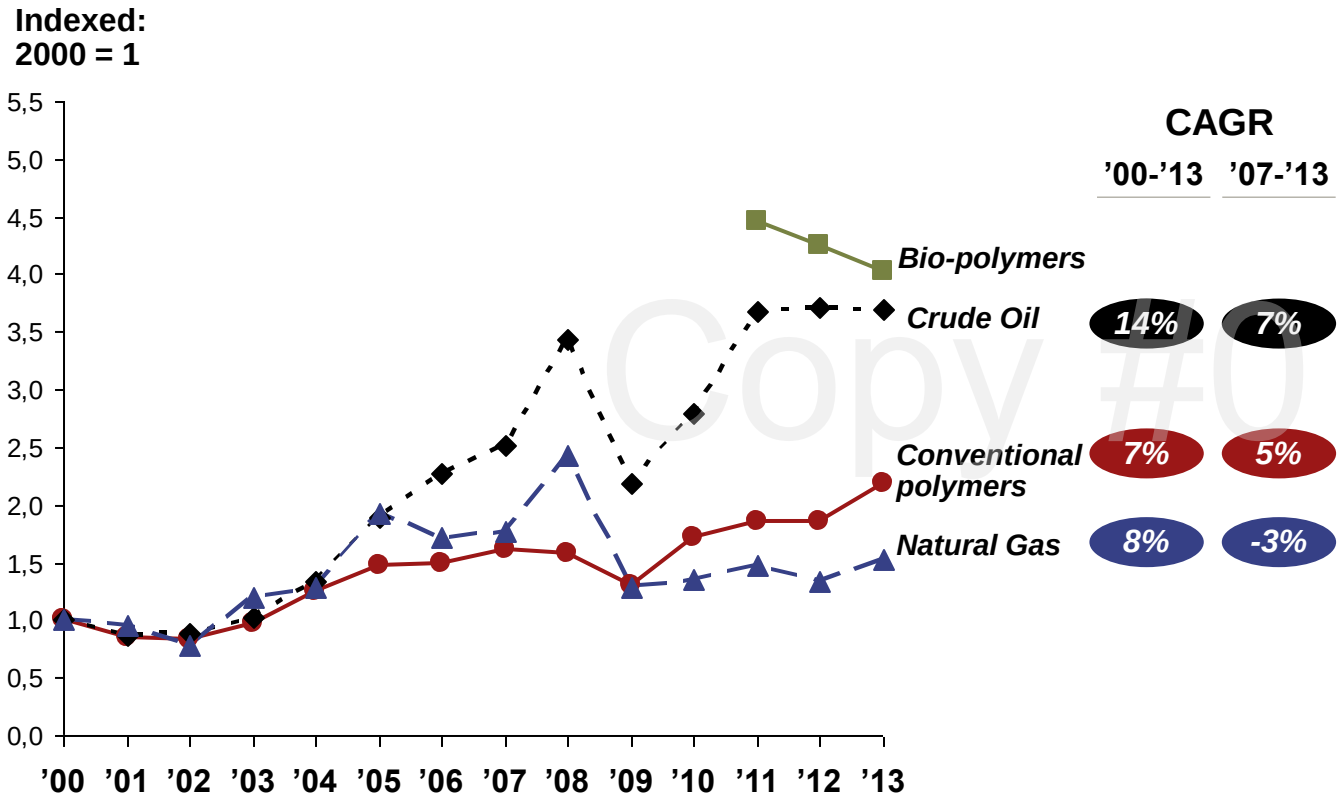
Conventional plastics prices increased over time, partly due to oil and gas costs, bio-plastics prices are higher but decreasing

Plastics prices – conventional vs. bio- vs. crude oil and gas



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Price main drivers

Crude Oil and Natural gas

- Global demand
- Oil / Gas scarcity concerns
- Technology innovation (lowering cost of supply)
- Weather conditions

Conventional polymers

- Crude oil and gas prices, being both raw material and energy source for plastic production

Bio-polymers

- Price of raw material / sub-products
- Efficiency in production process (economies of scale)

Source: World Bank, European Bioplastics, Bloomberg, Technavio, A.T. Kearney analysis

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  - Bio-plastics market growth projections and key success factors
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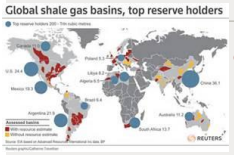
5 key external industry trends are impacting bio-plastics penetration in the market

Key trends impacting bio-plastics penetration	Impact
 • Increasing demand for **bio-friendly products**	+
 • Pressure from **regulators**, enforcing the use of bio-products – Directly: Substitution of a share of conventional plastics uses with bio-plastics in a determined timeframe – Indirectly: Emissions reduction	+
 • **Volatility** of **oil and gas prices,** driving interest in feedstock diversification to reduce exposure to hydrocarbon	+
 • **Geographical dynamics,** with higher / lower access to alternative feedstock	=
 • **End-of-life options** additional / alternative options, more inclined towards composting than recycling	=

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Source: Interviews with experts, A.T. Kearney analysis

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An array of companies already announced their efforts towards sustainability to address increasing demand

Companies publicly committed towards sustainability

Selection

Company	Industry	Initiative
Coca-Cola	Food & Beverage	Wants to source 25% of PET (over half its packaging material) from recycled or renewable material by 2015
pepsi	Food & Beverage	Will launch a pilot project for fully renewable PET bottle in 2012. Compostable bags for Sun Chips
Ford	Automotive	Currently using recycled and renewable materials such as soy-based polyurethane foams; all sustainable materials must be competitively priced against traditional materials
Walmart Save money. Live better.	Retail	Set a target of reducing GHG emissions in its supply chain by 20mtpa within 2015, much of which it is expected to be facilitated by suppliers
P&G	Home / Health care	By 2020 it aims for 25% of its fossil fuel-based raw materials to be replaced by renewable materials

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Increase in demand pulls bio-plastics development, with focus on bio-PET, positively impacting its penetration in the market

Source: Morgan Stanley, A.T. Kearney analysis

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Goal of emissions reduction is driving bio-plastics development with different extents according to different countries' norms

Normative context by region

North America

- Environmental protection agency (**E.P.A**.) **proposal** (2014): **30% reduction** of America's **carbon dioxide** emissions from 2005 levels by 2030. The methodologies should be defined by single states by 2016.
- **Formal commitment** of U.S.A. president to **emissions' reduction**

South America

Currently no incentives

Europe

- **«Europe 2020»,** R&D: 3% of EU's gdp has to be invested in R&D. Climate change and energy: **20% emissions' reduction** from 1990 level by 2020.
- **«Horizon 2020»: Financial support** provided to research on **innovative products**
- **Reduction** of **consumption** of **lightweight plastic** (<50 µm, e.g. shoppers) of **50% by 2017** – Italy enforced compliance with biodegradability and disintegration standards, fostering Mater Bi penetration
- **Official statements** from EU commission to **eliminate landfill disposal**

Asia Pacific

- **Japan**: «Biotechnology Strategic Scheme» & «Biomass Nippon Strategy» aimed at fostering **replacement of 20% of conventional plastics** with **ones from renewable sources by 2020.**
- **Korea**: «Strategy for promotion of industrial biotechnology (2012)» aimed to **replace 4,8% of crude oil imports with biochemical products** and reducing carbon dioxide emissions by approximately 10,8% by 2020.

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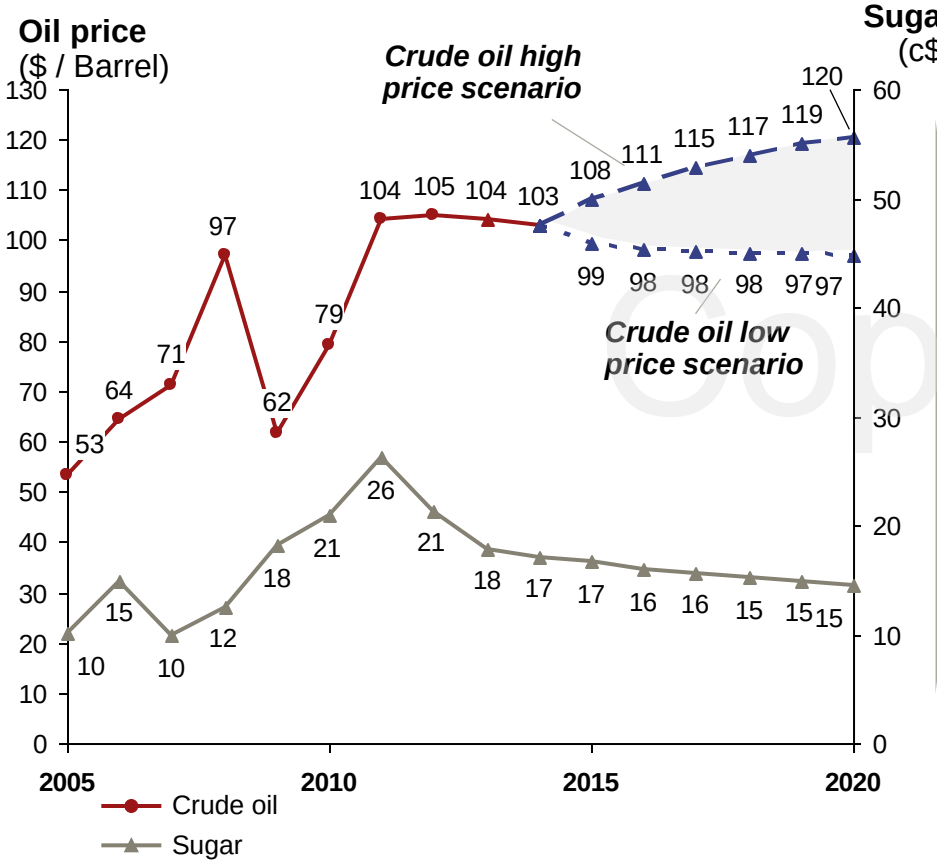
Source: European Bioplastics, A.T. Kearney analysis

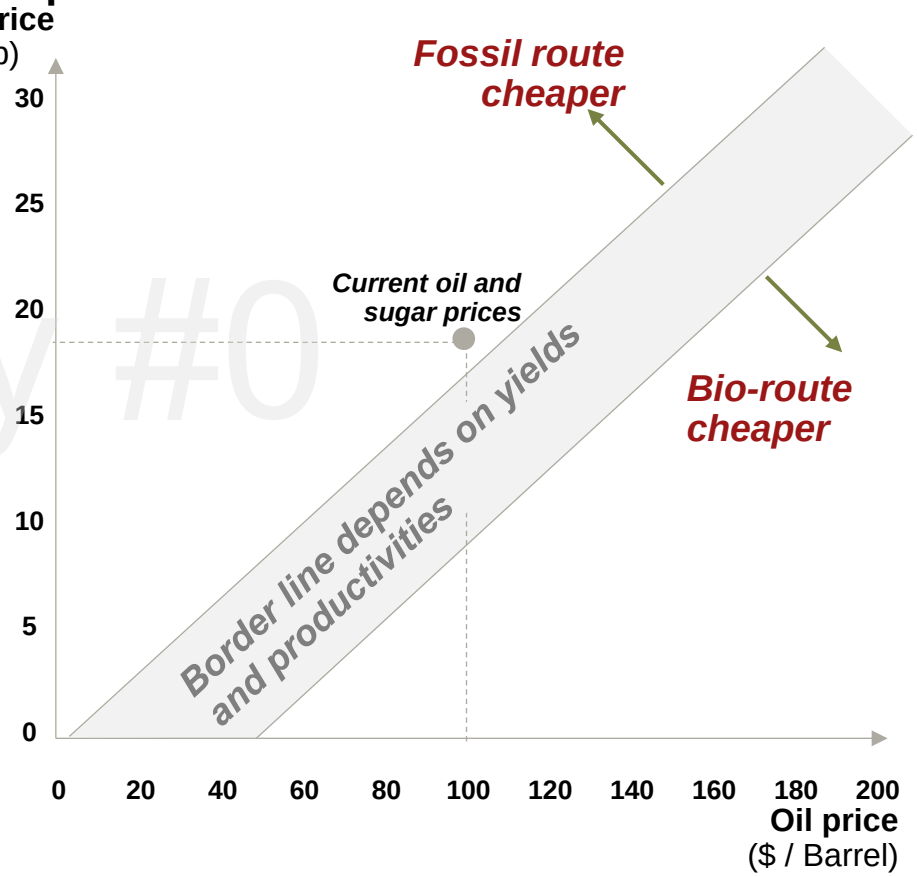
Crude oil volatility and highly uncertain future trends foster use of alternative sources, competitiveness of bio-routes is not far

Impact of crud oil prices volatility on bio-plastics penetration

Crude oil and sugar prices



Competitiveness of bio- vs fossil- based production routes



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Source: Mogan Stanley, World Bank, Interviews with experts, A.T. Kearney analysis

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Focus on renewable chemistry has a geographical connotation, driven by feedstock dependence and availability of raw material

Regional dynamics on bio-plastics development

North America

- **Low focus** on renewable chemistry
- **Chemical sector** heavily **based** on **ethane**, price of which has fallen due to development of shale gas reserves

Europe

- **Leading the way** in developing **bio-based products**
- **Chemical industry** strongly dependent on **naphtha** as a feedstock

Asia Pacific

- **Leader** with Europe in **developing bio-based** products
- **Chemical industry** strongly dependent on **naphtha** as a feedstock

South America

- **High attention** on bio-based products
- Higher **focus** as a **producer than** as a **consumer**, given the ready availability of sugar cane syrup and carbohydrate-rich bagasse

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Europe and Asia will lead the way on bio-plastics development, supported by South America, driven by ready availability of raw material

Source: Morgan Stanley, European Bioplastics, Interviews with experts, A.T. Kearney analysis

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Plastics end-of-life is still an open debate, disposal and composting are the most suitable options for bio-plastics

Plastics end-of-life options

	Description	Pro's	Con's	Most suitable for…
Landfill disposal	• **Plastics are stocked in a** well-defined **site**	• **It is an easy** and well-known **technique** • Low-cost method	• **Pollution risks** if not properly stored • **No benefits** provided • **Temporary** solution • **Space-consuming**	**Bio-plastics**
Incineration	• **Plastics combustion** aimed at **producing energy**	• **Landfill volume reduction** (90-99%) • **Suitable for all plastics** (Bio-PE=PE as power generated) • **Same emissions level than composting**	• **Low energy production from 100% bio-polymers**	**Conventional plastics**
Recycling and monomer recovery	• **Cleaning and re-distribution** of the **same product** • Product is **melted** and **re-moulded** to **create either the same or a different product**	• **Better environmental impact** compared with incineration and composting	• More **complex process** than for glass or metals • **Separation needed by plastic** types • Performance **problem with 100% Bio-polymers**	**Conventional plastics**
Composting	• **Plastics transformation** into **minerals** and **biomasses** • The result of the transformation works as **natural fertilisers**	• **Cost effective alternative** to standard landfill cover • It **reduces the need for chemical fertilisers**	• Eligibility: **specific features in terms of biodegradability** and **disintegration** of plastics are **required**	**Bio-plastics**

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Source: European Bioplastics; Plastice, Jefferies, OECD, A.T. Kearney analysis

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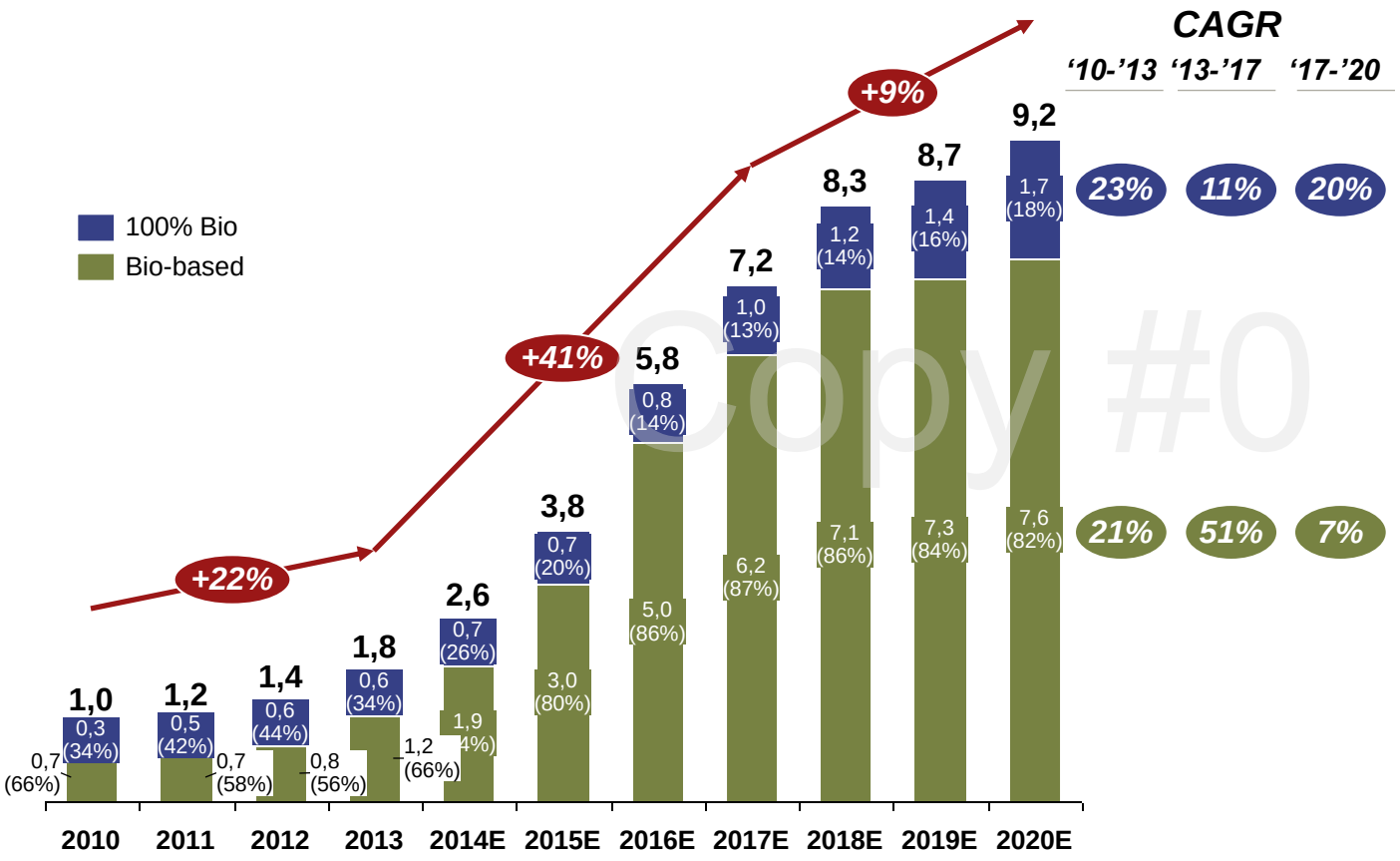
As of now, Bio-plastics growth projections show a double digit CAGR, driven by bio-based polymers

Global Bio-plastics production projection (Mln tons)



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Rationale

- **Bio-plastics production** expected to **grow by 5x** from 2011-2016, driven by bio-based products
- **Main driver** for bio-plastics growth is **bio-PET,** thanks to **surging demand from large manufacturers** of carbonated drinks
- **Lack of biodegradability** of bio-based products **is not seen as a issue** as they can be recycled using existing systems
- **100% biodegradable** product are expected **to earn share in a second phase** (2016 onwards), with a **20% CAGR** vs. 7% of Bio-based

Source: Morgan Stanley, Prodound, Nova Institute, European Bioplastics, ICIS, Interviews with experts, A.T. Kearney analysis

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Bio-plastics penetration potential is based on 3 key success factors

Bio-plastics penetration key success factors

1 **Performance**

Bio-polymer **capacity** to **replicate** conventional **polymers characteristics** (e.g. flexibility, fusion temperature, resiliency, …) and cover their **scope of applications**

2 **Complexity**

Bio-polymer **impact on value chain** and capacity to **ramp-up** quickly **to commercial scale**

3 **Cost of production**

Bio-polymer **competitiveness** in terms of **costs** of **production** vs. conventional polymers

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Source: A.T. Kearney analysis

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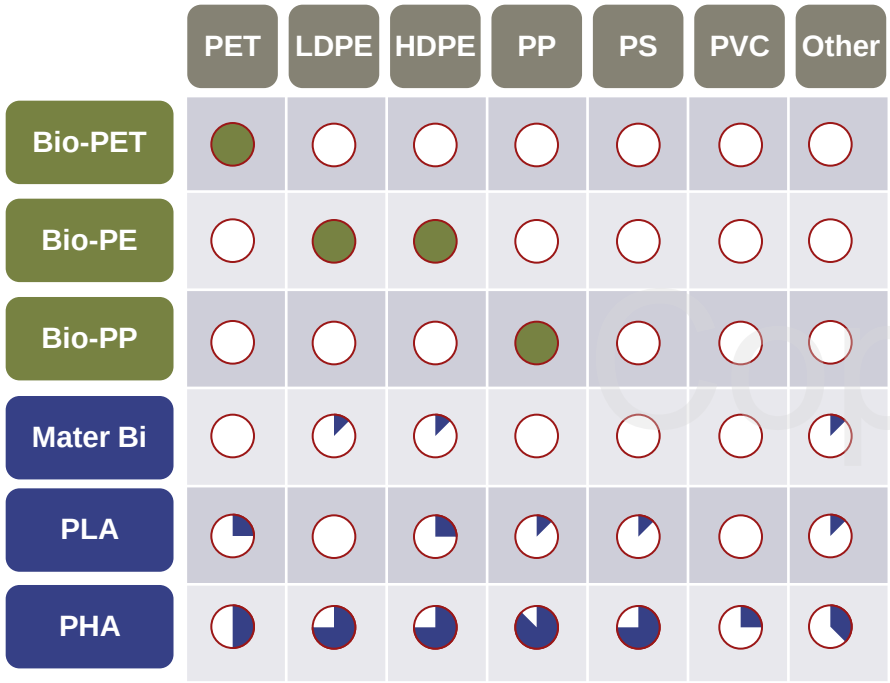
100% bio-products cover a wider range of applications, with PHA able to substitute most of polymers

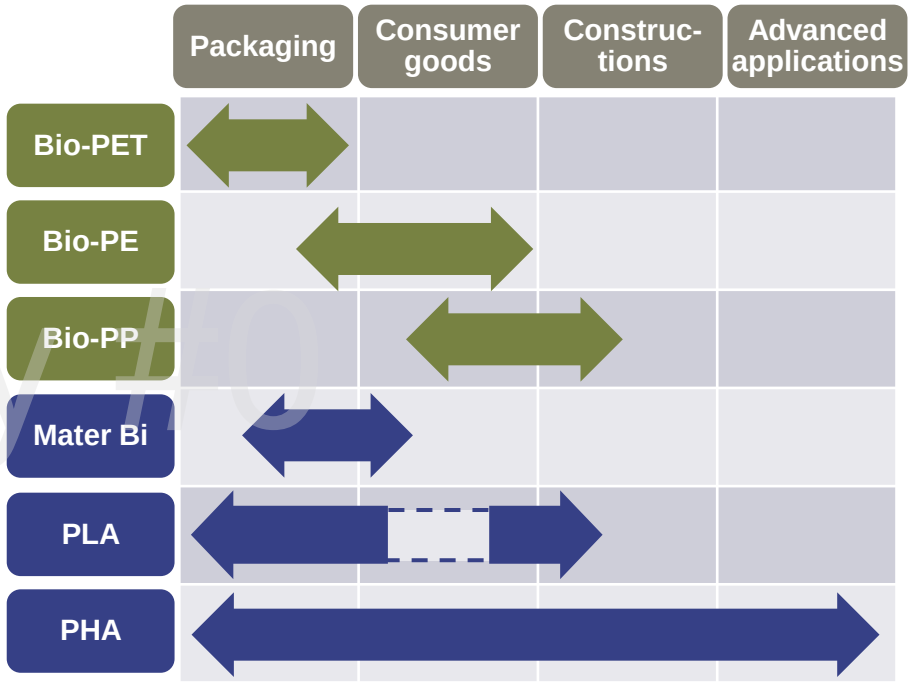
Key success factors - Performance

Technical substitution of bio-polymers



- **Bio-based** products **fully substitute their** petrol-based **counterpart**, not other polymers
- **100% Bio** products **substitute** a wide **range of polymers**, **PHA** with a **higher rate** of substitution

Segments of application of bio-polymers



- Bio-based polymers cover **selected segments of applications**
- **100% Bio** cover a **wider range** of **applications,** with **PHA covering most of them**

Source: Morgan Stanley, Interviews with experts, A.T. Kearney analysis

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Bio-based value chain requires very few changes to become productive, PHA impacts production less than other 100% Bio

Plastic value chain

Provision of raw material | ***Chemical production***

Oil extraction	Oil transformation	Plastic production	Plastic compounding	Plastic conversion	Plastic product commercializ.	Consumer
Drilling & extraction of crude oil	*Oil transformation for commercialization*	*Production of plastic powder*	*Powder formulation through product compounding*	*Pellet conversion into final product*	*Product commercialization in the market*	






Players involved

Bio-based	*New raw material provider involved*	*Same actors as for conventional*	*Same actors as for conventional*
100% bio	*New raw material provider involved*	*New actors involved (biologists)*	*Same actors as for conventional*

Production processes

Bio-based	*Different process of raw material transformation*	*Same processes as for conventional*	*Same processes as for conventional*
100% bio	*Different process of raw material transformation*	*New expertise needed for production (fermentation) and compounding*	***PHA**: Same processes as for conventional* ***Others**: new expertise needed for conversion*

Impact on Value chain | *No impact on Value chain*

Source: Morgan Stanley, Interviews with experts, A.T. Kearney analysis

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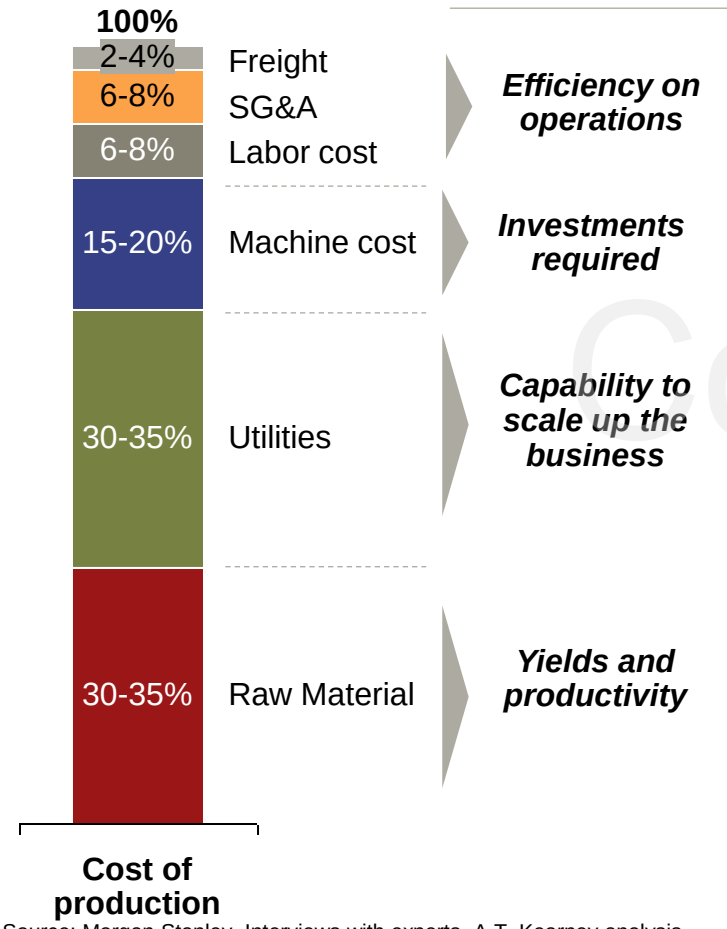
Bio-based are already competitive with conventional polymers, 100% bio needs to focus first on niche applications

Key success factors – Cost of production



Main cost drivers

- ***Efficiency on operations***
- ***Investments required***
- ***Capability to scale up the business***
- ***Yields and productivity***

Potential Target

Bio-based polymers

- **Few investments required** for plastic producers, given similarities with operations already in place
- **High capability** to **scale up the business,** as the end product is the same as conventional plastics
- **Medium / low yields**, driven by use of different raw material
- **High productivity**, in line with production of conventional

High volume, low margin applications

100% bio polymers

- **Mid-high investments required** on upstream value chain (lower for PHA, where no change in transformation machines is needed)
- **Limited possibilities** to **scale up** the business in the short term, due to introduction of **new processes and products**
- **Mid / low yields and productivity**, due to new raw materials

Low volumes, high margins applications

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Source: Morgan Stanley, Interviews with experts, A.T. Kearney analysis

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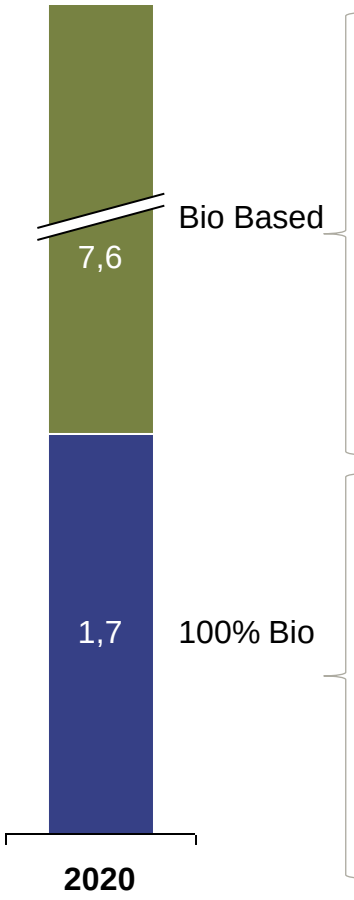
Expected growth for Bio-based and PHA seem feasible - PLA and other 100% Bio growth is the biggest question mark



Main growth drivers	Level of confidence	Rationale
Growth of Bio-PET	●	• **Big multinationals** (e.g. Coca-cola, Nike, P&G) already announced commitment to **join "PTC[1]"**, a working group for **development and use of Bio-PET** • **Plants easy to convert to** production of **Bio-based** polymers • **Cost efficient** in the **short term** • Full **substitution of single polymers**
Growth of other Bio-based polymers in **the short term**	◔	
Growth of PHA in the **long term**	◔	• **Potential substitute** for a **wide range** of **polymers** in nearly all the **applications** ✓ **Almost no alternatives** on selected **technically advanced applications** • **Lower impact on Value chain** vs. **other 100% bio** • **Limited possibilities to scale up the business**
Growth of PLA and other 100% bio (e.g. MaterBi) in the **long term**	◔	• **High competition** coming **from bio-based and PHA**: ✓ Narrower range of applications ✓ Higher impact on value chain ✓ Economies of scale key to compete

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1 PTC = PET Technology Collaborative
Source: A.T. Kearney analysis

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Agenda

- Project objectives and approach
- Current plastics industry overview
- **Bio-plastics market growth assessment**
  - Bio-plastic penetration drivers
  - Bio-plastics market growth projections and key success factors
  - **Key players dynamics**
- Evaluation of Bio-On PHA applications potential

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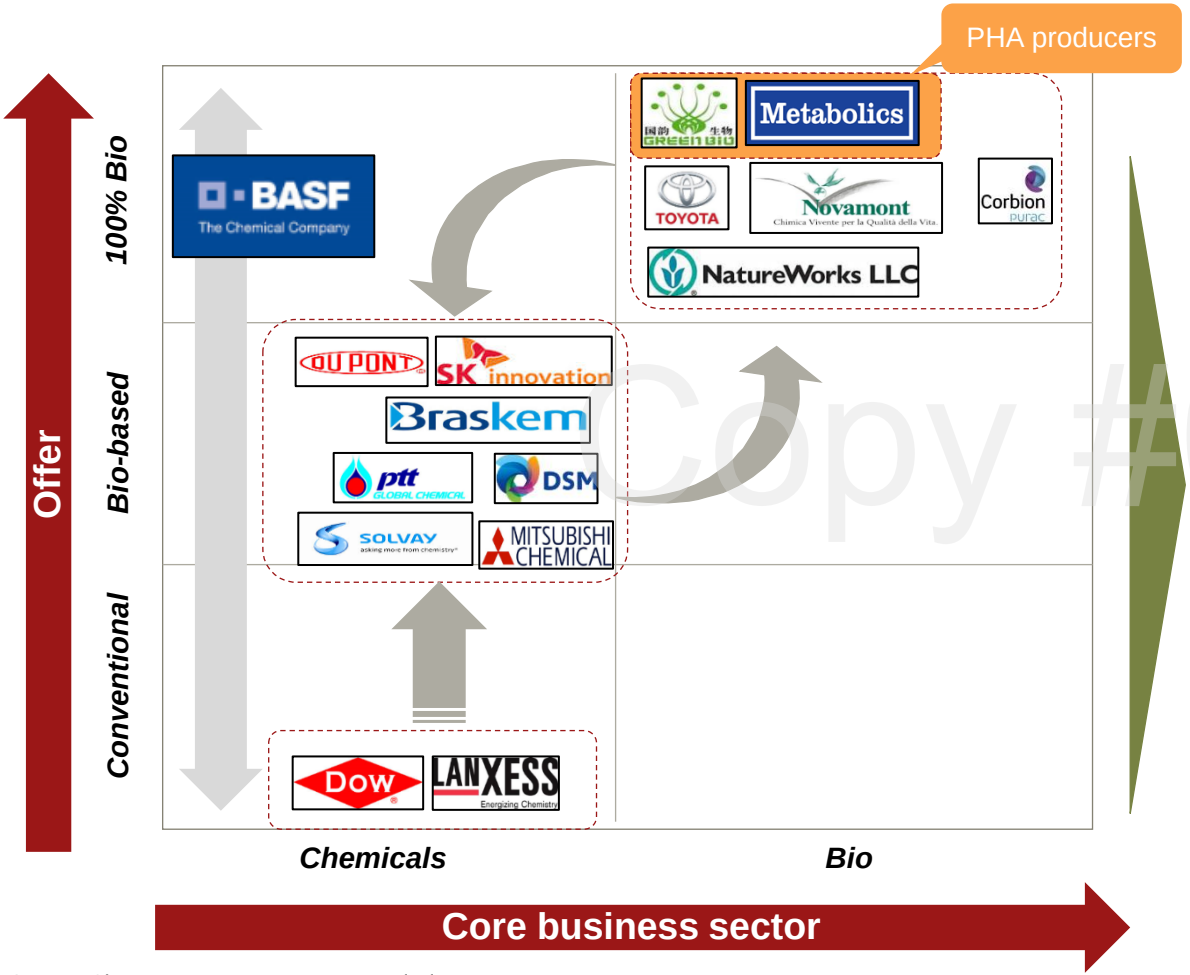
Chemical and Bio company entered the bio-plastics business with different products, BASF covers the entire product offering

Plastics/Bioplastics: competitive landscape

Selection



Highlights

- Most important **Chemical companies** already have **bioplastics in their product portfolio, though production seems still left to TPM**
- **Among chemical** companies, most **preferred solution** is **bio-based** products (e.g. Bio-PET, Bio-PE, …) -- often partnering with bio companies - due to the quick adaptability of their value chain
- **BASF** seems the **only company** that chose to **cover the entire product offering**
- **Bio Companies** instead entered the bio-plastics business **with 100% bio products**

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Source: Chemsystems, A.T. Kearney analysis

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Agenda

- Project objectives and approach
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- **Evaluation of Bio-On PHA applications potential**

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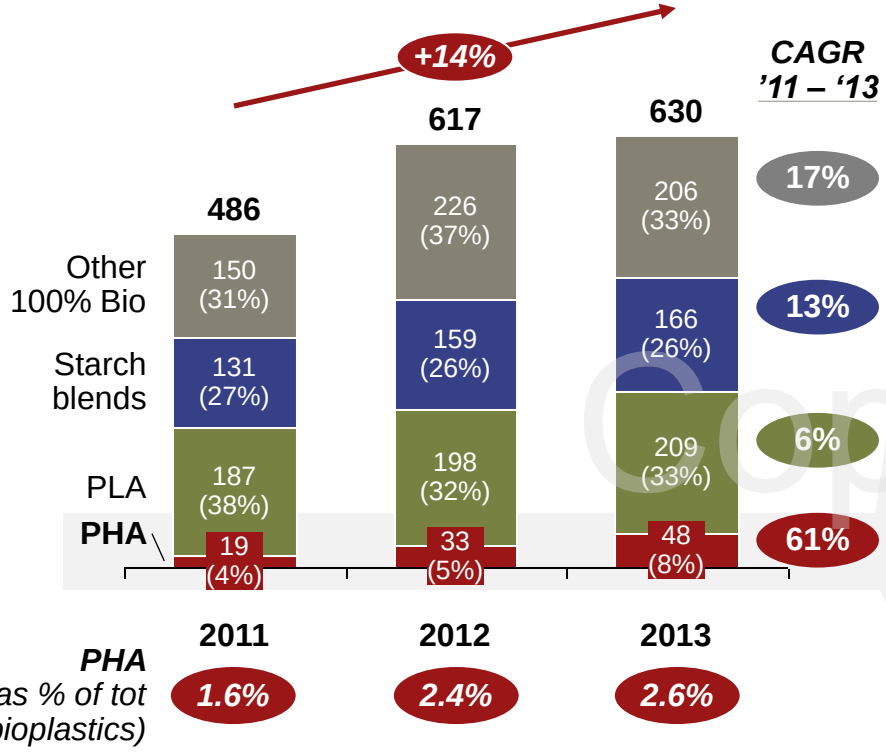
PHA outgrew other 100% Bio over the last 2 yrs thanks to higher performances, production cost hindered its deployment so far

100% Bio-products production (000 tons; %)



PHA position on KSF

Perfor-mance

- **Larger number of applications** vs. other Bio-plastics, given the array of polymers achievable from PHA
- **100% biodegradability** in all living forms

Complexity

- **Lower impact on value chain** vs. other 100% Bio
- Slightly **higher impact** on value chain vs. bio-based

Cost of production

- **Higher prices vs** vs. **bio-based** (~5 $/kg vs. ~2$/kg) due to **higher** production **costs**:
  - lack of scale economy in fermentation
  - lower productivity and yields

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Lack of production plants and availability on the market also limited PHA deployment

Source: European bioplastics, Profound, Interviews with experts, A.T. Kearney analysis

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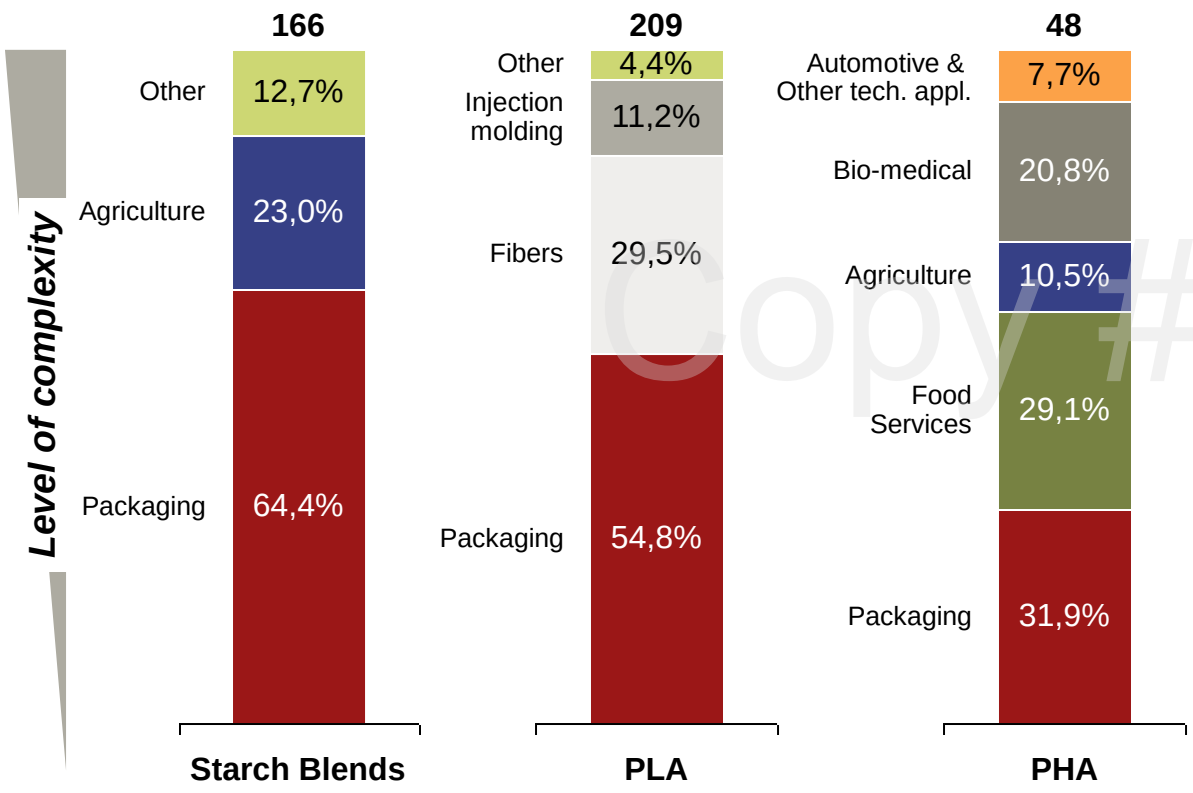
PHA applications embrace more advanced uses vs. other 100% Bio, with Bio-medical and Automotive accounting for ~30%

Starch blends, PLA and PHA split by application (000 tons; 2013)



Highlights

- **Starch blends** are the **weakest performer**, with majority of **applications** on **Packaging** (e.g. shoppers) and **Agriculture** (e.g. plastic films for greenhouse)
- **PLA shows a mid-level performance**: main segment of applications is still packaging (55%), but nearly 40% of end uses are for **fibers** (e.g. textile, mostly in Asia) and **injection molding** (e.g. consumer products)
- **PHA is the best performer** among 100% Bio, with **nearly 30%** of end uses focused on **Bio-medical** applications and **Automotive**

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Source: Profound, A.T. Kearney analysis

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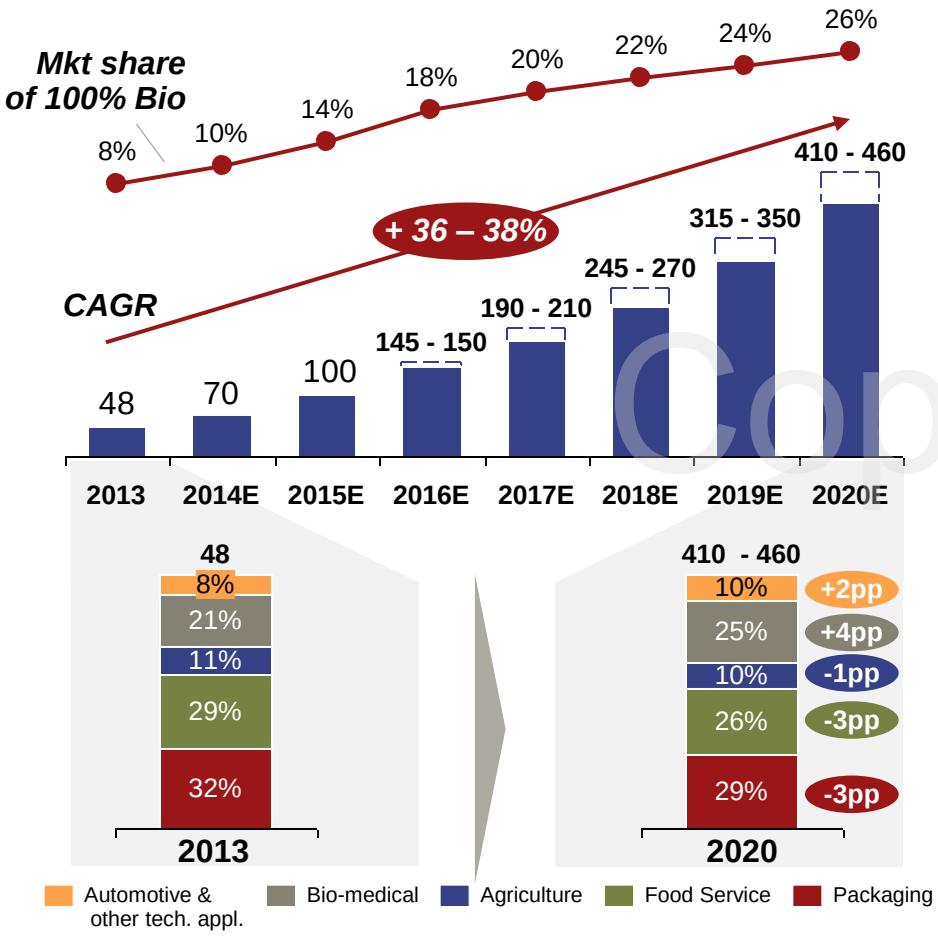
PHA is expected to overtake 400k tons in 2020, with 26% market share, driven by Bio-medical and other advanced applications

PHA production projections (,000 tons)



Rationale

- **PHA production** is expected to **grow between +36%** and **+38% CAGR** in 2020, reaching **26% market share** of total **100% Bio** polymers
- **Main drivers** for PHA **growth** are:
  - **Expected reduction** on **cost of production**, thanks to enhanced yields and utilization of cheaper feedstock (e.g. sugar molasses)
  - **High fit with bio-medical applications**, thanks to PHA complete bio-degradability and natural origin
  - **High level of substitution** on **technical applications** (e.g. automotive and electronics) where high performing / functional plastics are required and prices are premium
- **Increase** in **PHA market share** is driven **by** the relatively **high competition** other 100% Biopolymers (e.g. PLA and starch) will find **in commodity applications**, especially in the first years

Source: Profound, Nova institute, European Bioplastics, Interviews with experts, A.T. Kearney analysis

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