# Market study on bio-based building blocks and polymers in the world - Capacities, production and applications: status quo and trends toward 2020

# &

# Environmental aspects

# &

# $CO_2$-based polymers

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Roland Essel, Achim Rascka
nova-Institut GmbH, Hürth (Cologne), Germany

# Bio-based Economy – Bio-based Chemistry and Materials

## Departments

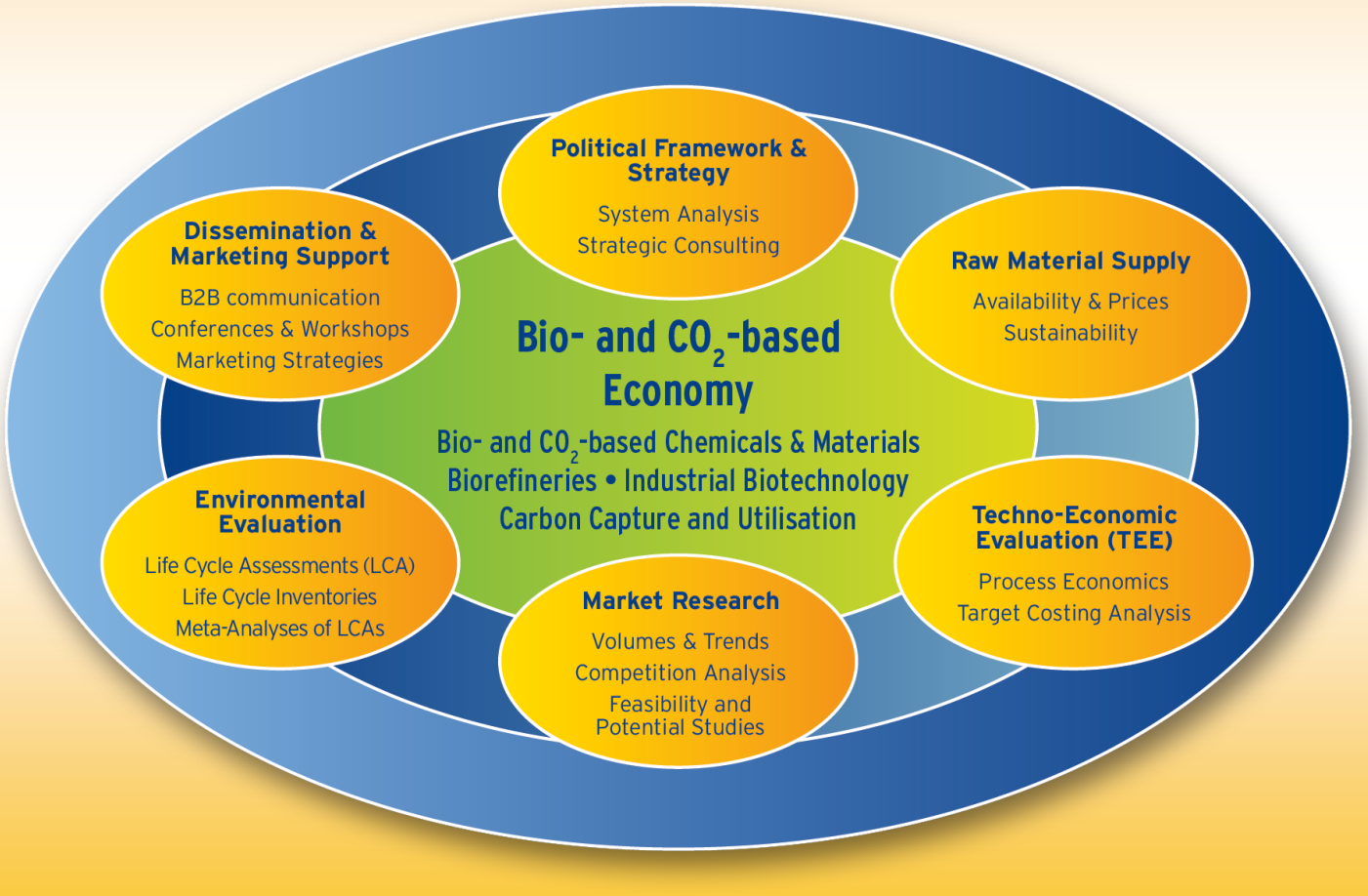
- Sustainability
- Economy & Policy
- Technology & Markets
- Communication

# nova-Institut GmbH – SME

## Founded in 1994 as a private and independent research institute
## 25 employees – interdisciplinary, international team

**Revenue shares**

- Research Projects
- Conferences & Dissemination
- Industrial & Political Consultancy



# Bio- and $CO_2$-based Economy – Services of nova-Institute

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## INFO

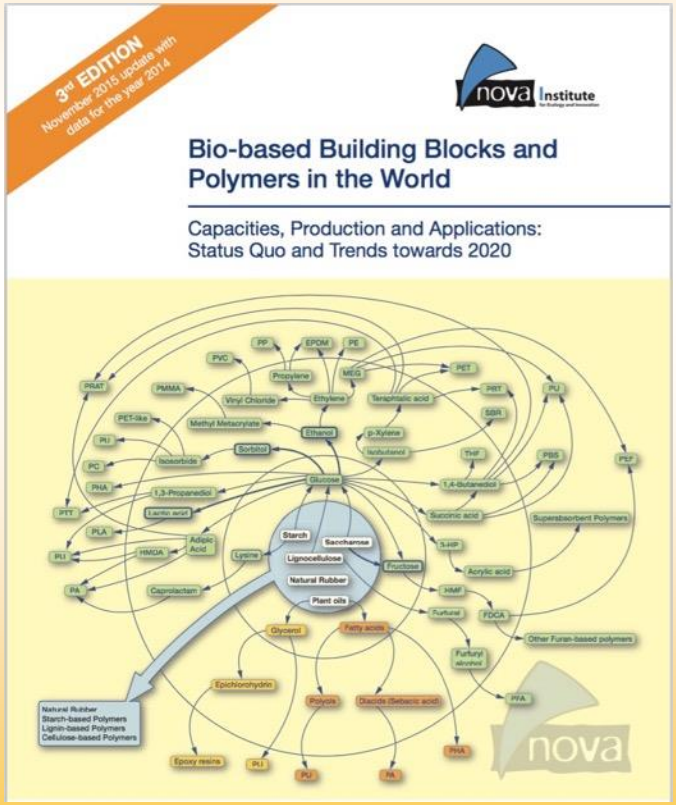
- **Bio-based News**
  Daily news on bio-based economy
- **iBIB**
  International Business Directory for Bio-based Materials
- **nova Sessions**
  Sessions on bio-based and $CO_2$-based economy
- **About nova**
  Institute for ecology and innovation
- **Press releases**
  News from nova

## CONFERENCES

- **9th International Conference on Bio-based Materials ("Biowerkstoff-Kongress")**
  Maternushaus, Cologne, Germany, 5 – 6 April 2016
- **Bio-based Start-up Day**
  Maternushaus, Cologne, Germany, 7 April 2016
- **13th International Conference of the European Industrial Hemp Association**
  Rheinforum, Wesseling, Germany, 31 May – 2 June 2016
- **5th Conference on Carbon Dioxide as Feedstock for Fuels, Chemistry and Polymers**
  Maternushaus, Cologne, Germany, 6-7 December 2016

# Market study

**“Bio-based Building blocks and Polymers in the World – Capacities, Production and Applications: Status Quo and Trends towards 2020” (nova-Institute 2015)**




**Comprehensive data and trend reports** written by experts (from Europe, Asia and US), about 500 pages, published in December 2015

Price: 3,000 €

Summary can be downloaded at:
www.bio-based.eu/markets/

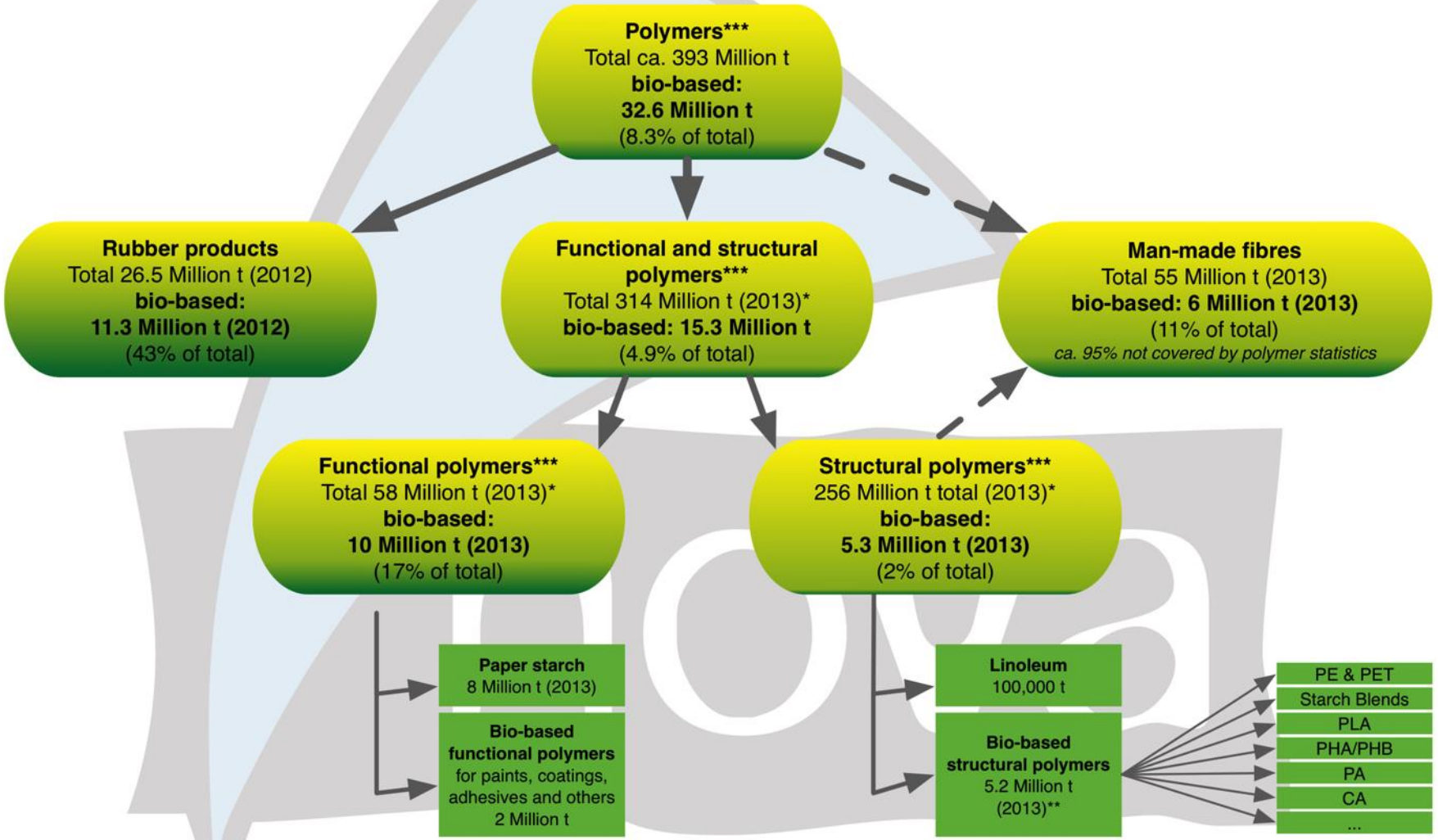
Basis of the European Bioplastics data, new graphs published on November 2015

# Trend reports

The **“trend reports**” section contains a total of 10 independent articles contributed by leading experts in the fields of bio-based polymers and building blocks (only main authors shown):

- **Dirk Carrez & Jim Philp:** Policies impacting bio-based plastics market development
- **Constance Ißbrücker & Harald Käb:** Plastic Bags – their consumption and regulation in the European market and beyond
- **Lara Dammer:** Standards, norms and labels for bio-based products
- **Jan Ravenstijn:** Bio-based polymers, a revolutionary change
- **Rainer Busch:** Bio-based monomers
- **Wolfgang Baltus:** Asian markets for bio-based chemical building blocks and polymers
- **Harald Käb:** Brand views and adoption of bio-based polymers
- **Roland Essel**: Environmental evaluation of bio-based polymers and plastics
- **Roland Essel:** Microplastics in the environment: sources, consequences, solutions
- **Michael Carus:** GreenPremium prices along the value chain of bio-based products

# Polymers worldwide, bio-based shares (2013)

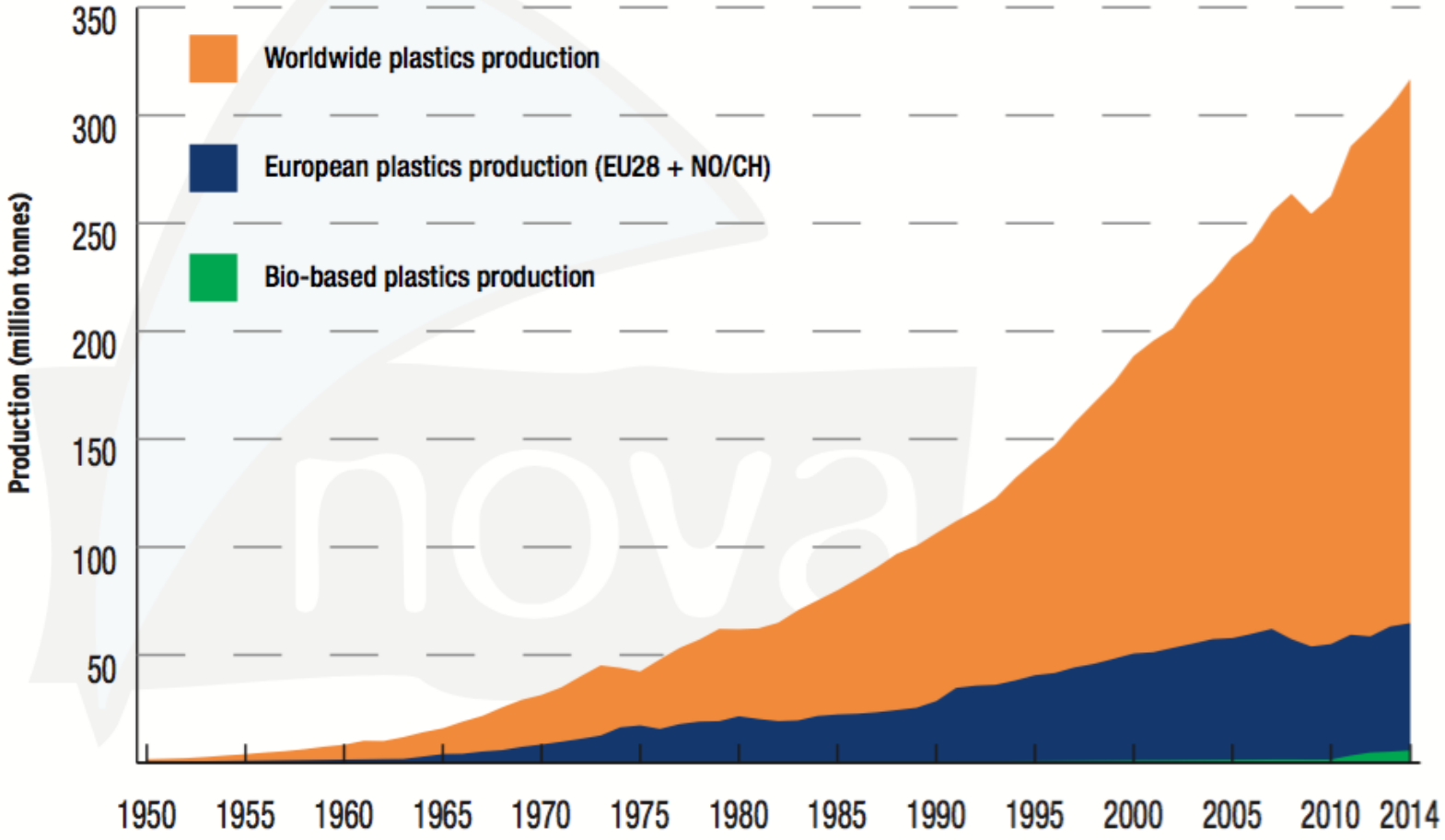



(*): Data from PlasticsEurope 2014. Original data show 299 Million tonnes for 2013 in total. With the same shares as 2011 (PlasticsEurope 2012) this would mean: 251 Million tonnes structural polymers and 48 Million tonnes functional polymers plus bio-based polymers (nova 2015); (**): nova-Institute 2015; (***): Polymers covering thermoplastic and thermosets; Different additional sources, like International Rubber Study Group (www.macplas.it, 13-07-10), The Fiber Year 2014 (14-05)



Full study at
www.bio-based.eu/markets

# Worldwide, European and bio-based plastics production from 1950 to 2014






*Includes plastics materials (thermoplastics and polyurethanes) and other plastics (thermosets, adhesives, coatings and sealants). Does not include the following fibres: PET-, PA-, PP- and polyacryl-fibres.

Data source: PlasticsEurope and nova-Institute

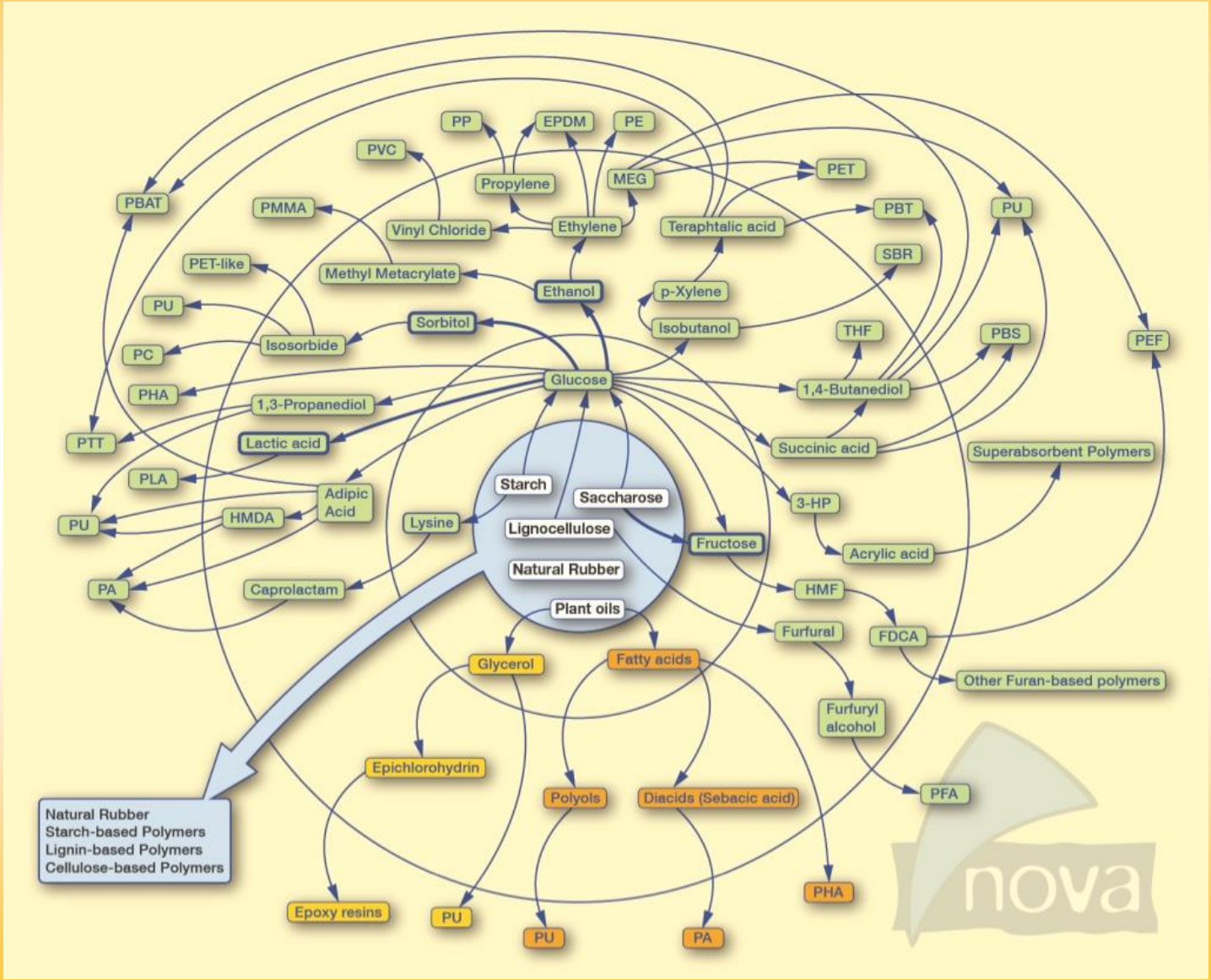
# Scope of the nova market study

**NEW:** Bio-based polymers + bio-based building blocks

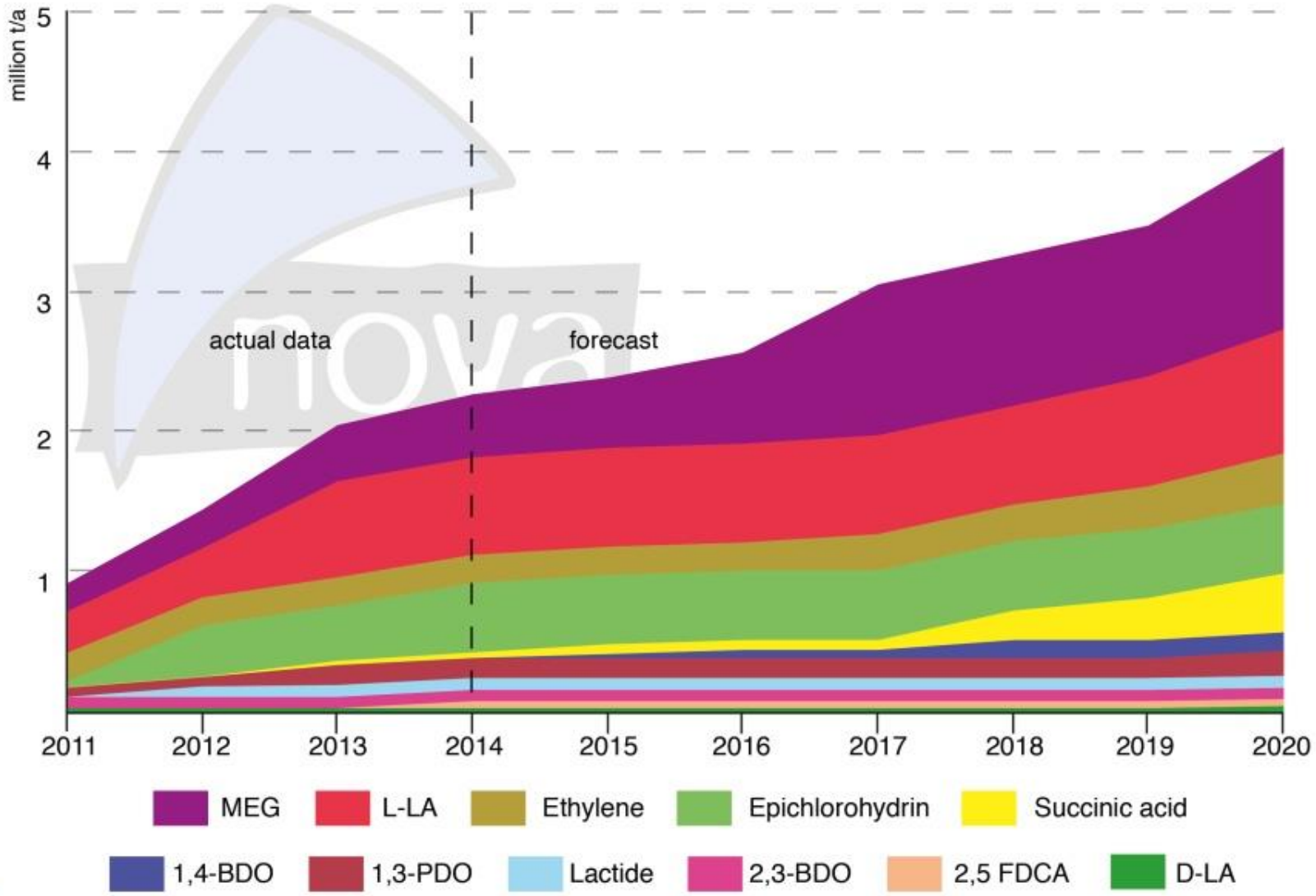
## Which bio-based building blocks are considered?

- Monoethylene glycol (MEG)
- Lactic acid (LA)
- Ethylene
- Epichlorohydrin
- Succinic acid
- 1,4-Butanediol (1,4-BDO)
- 1,3-Propanediol (1,3-PDO)
- 2,5-Furanedicarboxylic acid (2,5-FDCA)

# Free poster available



# Selected bio-based building blocks: Evolution of worldwide production capacities from 2011 to 2020






Full study available at www.bio-based.eu/markets

# Bio-based polymer producers and production capacity 2012-2014

| BIO-BASED STRUCTURAL POLYMERS | | CURRENT BIO-BASED CARBON CONTENT* | PRODUCING COMPANIES IN 2014 AND UNTIL 2020 | LOCATIONS IN 2014 AND UNTIL 2020 | 2012 | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | PRODUCTION CAPACITIES (TONNES) | PRODUCTION CAPACITIES (TONNES) | CAGR 2012-2013 | PRODUCTION CAPACITIES (TONNES) | CAGR 2013-2014 |
| Cellulose acetate | CA | 50% | 15 | 16 | 835,000 | 845,000 | 1% | 855,000 | 1% |
| Epoxies | – | 30% | – | – | 1,120,000 | 1,210,000 | 8% | 1,520,000 | 26% |
| Ethylene propylene diene monomer rubber | EPDM | 50% to 70% | 1 | 1 | 45,000 | 45,000 | 0% | 45,000 | 0% |
| Polyamides | PA | 40% to 100% | 9 | 12 | 65,000 | 85,000 | 31% | 95,000 | 12% |
| Poly(butylene adipate-co-terephthalate) | PBAT | Up to 50%** | 4 | 5 | 75,000 | 75,000 | 0% | 95,000 | 27% |
| Polybutylene succinate | PBS | Up to 100%** | 10 | 11 | 125,000 | 125,000 | 0% | 125,000 | 0% |
| Polyethylene | PE | 100% | 1 | 1 | 200,000 | 200,000 | 0% | 200,000 | 0% |
| Polyethylene terephtalate | PET | 20% | 5 | 5 | 450,000 | 600,000 | 33% | 600,000 | 0% |
| Polyhydroxyalkanoates | PHA | 100% | 16 | 19 | 30,000 | 32,000 | 7% | 35,000 | 9% |
| Polylactic acid | PLA | 100% | 27 | 33 | 180,000 | 195,000 | 8% | 205,000 | 5% |
| Polytrimethylene terephthalate | PTT | 27% | 2 | 3 | 90,000 | 120,000 | 33% | 120,000 | 0% |
| Polyurethanes | PUR | 10% to 100% | 7 | 7 | 1,100,000 | 1,200,000 | 9% | 1,400,000 | 17% |
| Starch blends*** | – | 25% to 100% | 15 | 16 | 365,000 | 400,000 | 10% | 395,000 | -1% |
| Total | | | 112 | 129 | 4,680,000 | 5,132,000 | 10% | 5,690,000 | 11% |

* Bio-based carbon content: fraction of carbon derived from biomass in a product (EN 16575 Bio-based products – Vocabulary)

** Currently still mostly fossil-based with existing drop-in solutions and a steady upward trend

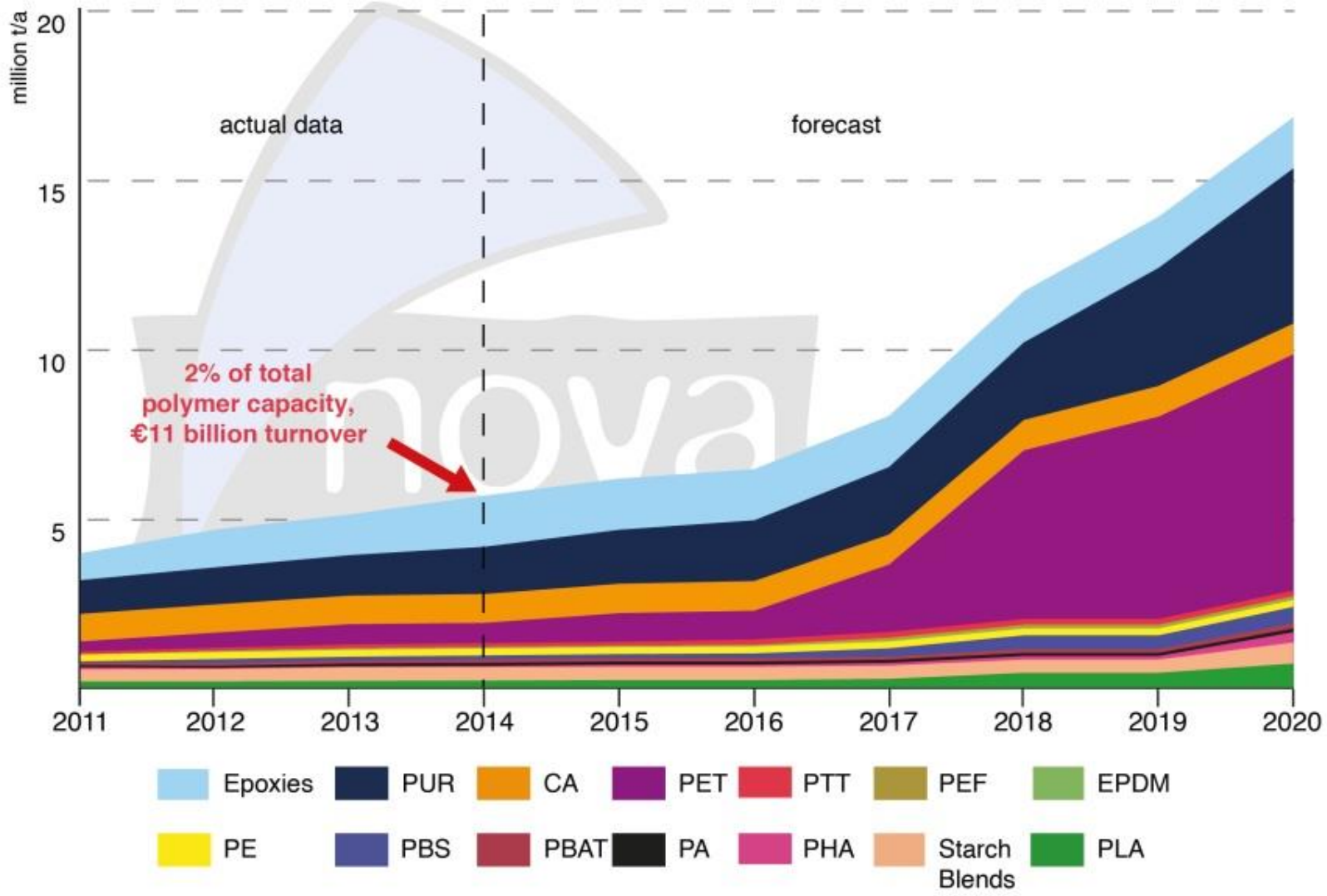
*** Starch in plastic compound

Green: Growth over the previous year



Full study available at www.bio-based.eu/markets

# Bio-based polymers: Evolution of worldwide production capacities from 2011 to 2020






Full study available at www.bio-based.eu/markets

# Bio-PET

**Today five companies produce Bio-PET**:

- Indorama Ventures (Indonesia), mainly for CocaCola
- Teijin Limited (Japan)
- Toray (Japan)
- Toyota Tsusho (Japan) (MEG from Greencol Taiwan)
- Polyplex (India)

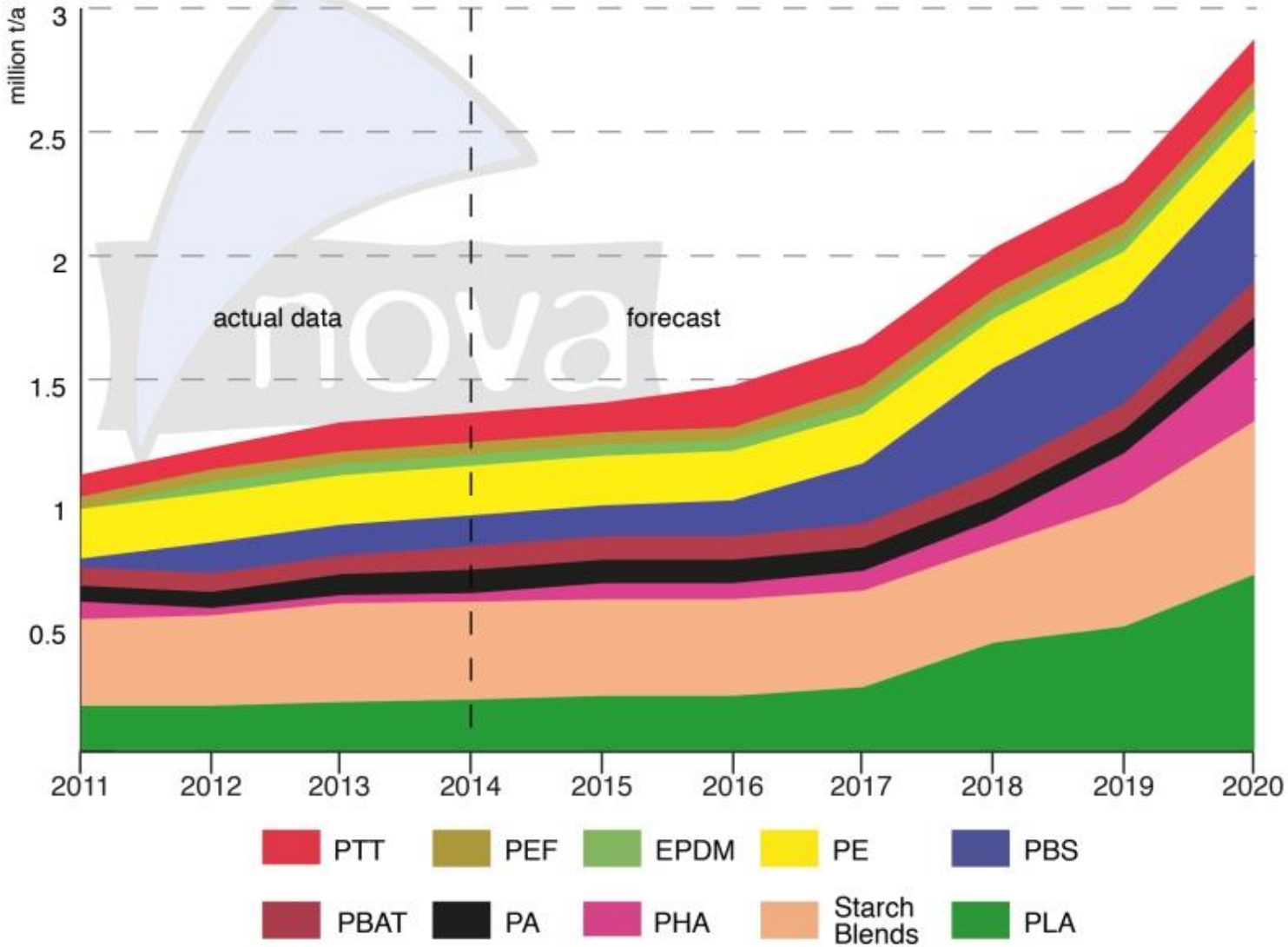
**Bio-PET capacities:**

- in 2011: 300,000 tonnes
- In 2013/14: 600,000 tonnes
- In 2020: 7 Million tonnes

Biomass content ca. 30%
Bio-based carbon content ca. 20%

**Price:**
Early 2015 Bio-PET is about two times more expensive compared to petrochemical PET (because of cheap crude oil); for high volumes (CocaCola) it is only 1.25 – 1.5 times more. Price parity is expected before 2020.

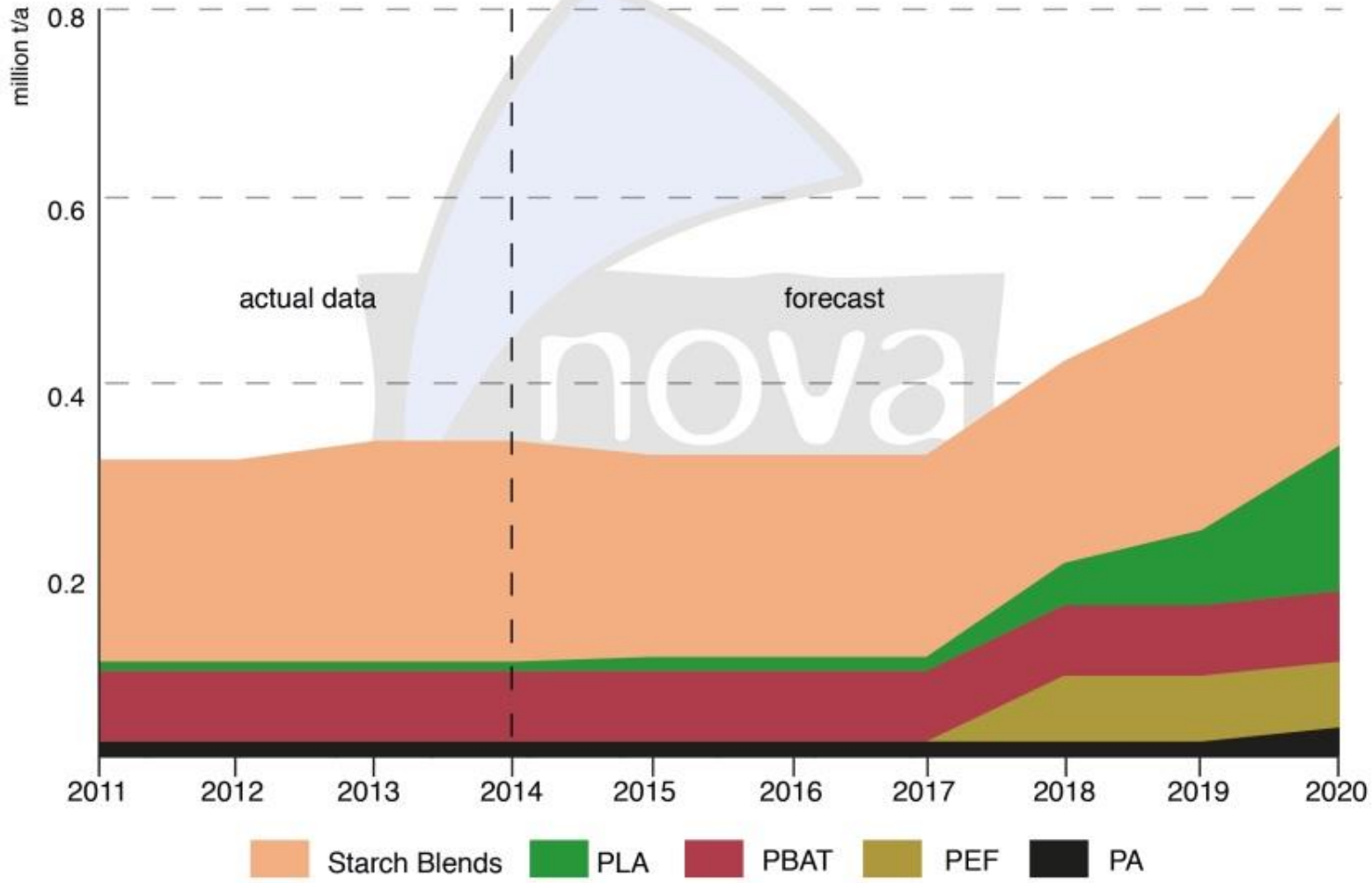
# Selected bio-based polymers: Evolution of worldwide production capacities from 2011 to 2020






Full study available at www.bio-based.eu/markets

# Bio-based polymers: Evolution of production capacities in Europe from 2011 to 2020 (without thermosets and cellulose acetate)



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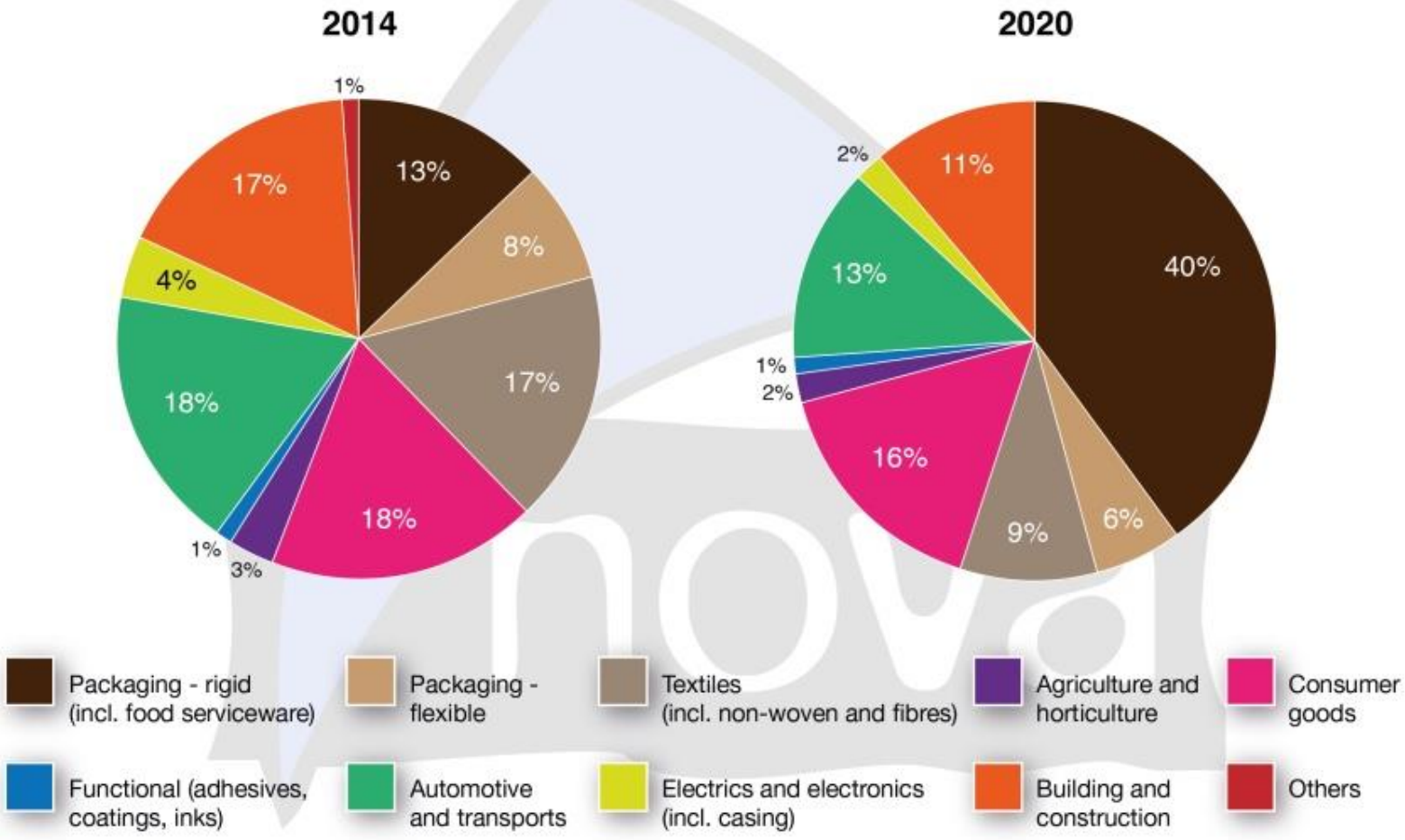
# Worldwide shares of bio-based polymers production in different market segments in 2014 and 2020



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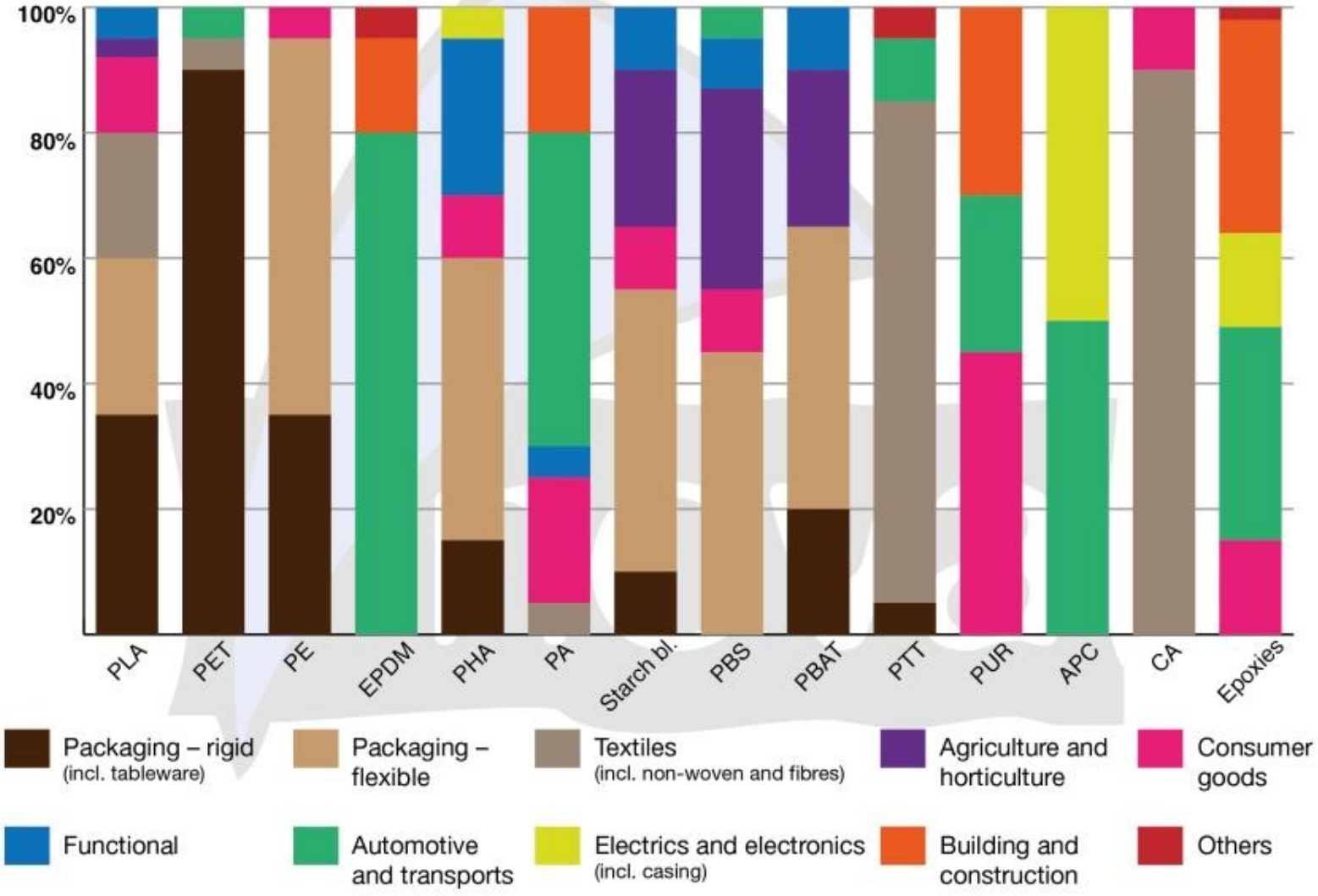
# Shares of market segments per bio-based polymer in 2014






Full study available at www.bio-based.eu/markets

# Scope of the „European Bioplastics“ data

## Which bio-based polymers are considered?

**→ Only thermoplastics (biodegradable or not), no thermosets**

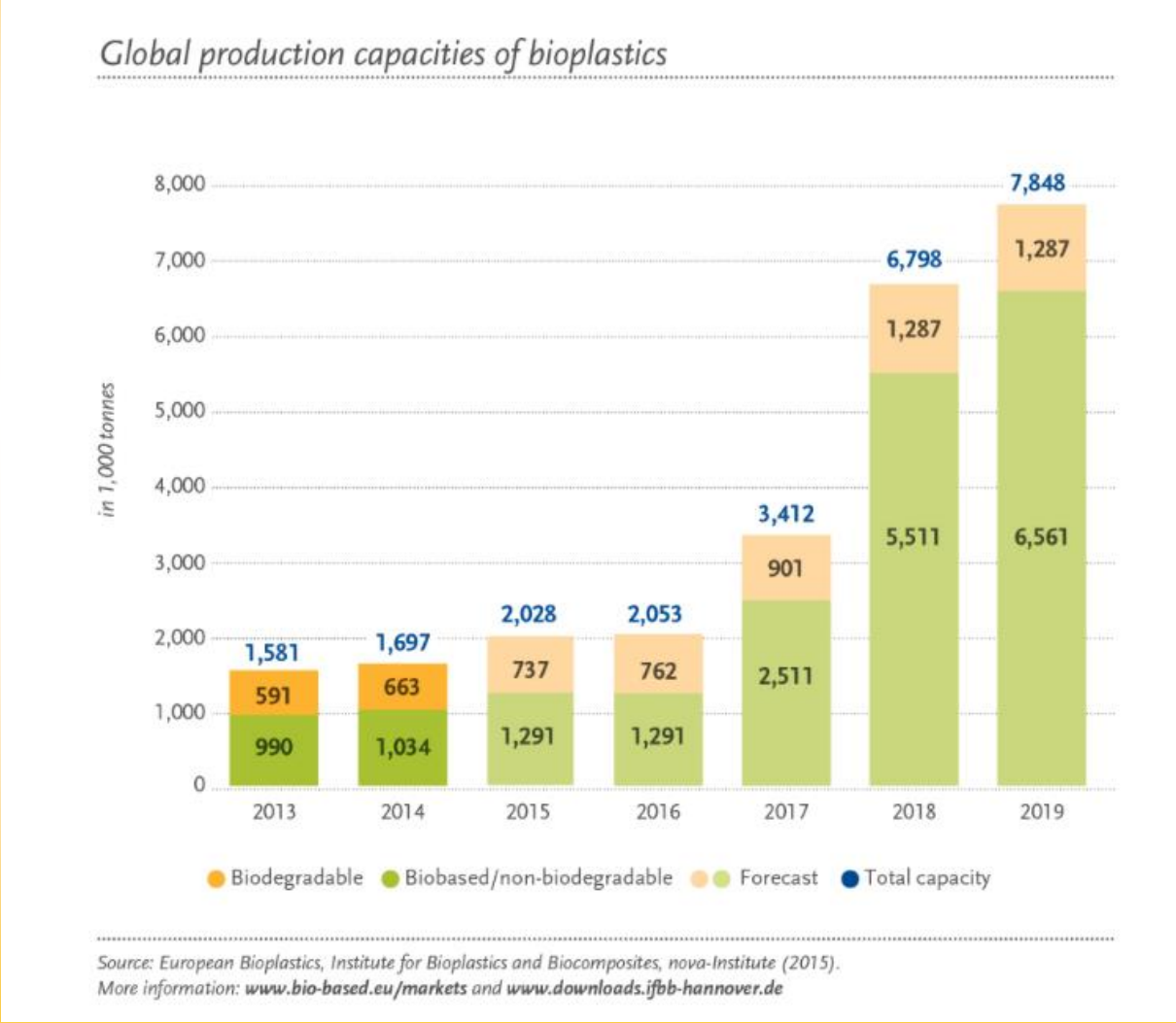
- Polylactic acid (PLA)
- Polyhydroxyalkanoates (PHAs)
- Polyethylene (PE)
- Polyethylene Terephthalate (PET)
- Polyethylene Furanoate (PEF)
- Polybutylene Succinate (PBS)
- Polybutylene adipate-co-terephthalate (PBAT)
- Polyamide (PA)
- Polytrimethylene terephthalate (PTT)
- Aliphatic polycarbonate (APC)
- Starch blends

**Not included:**

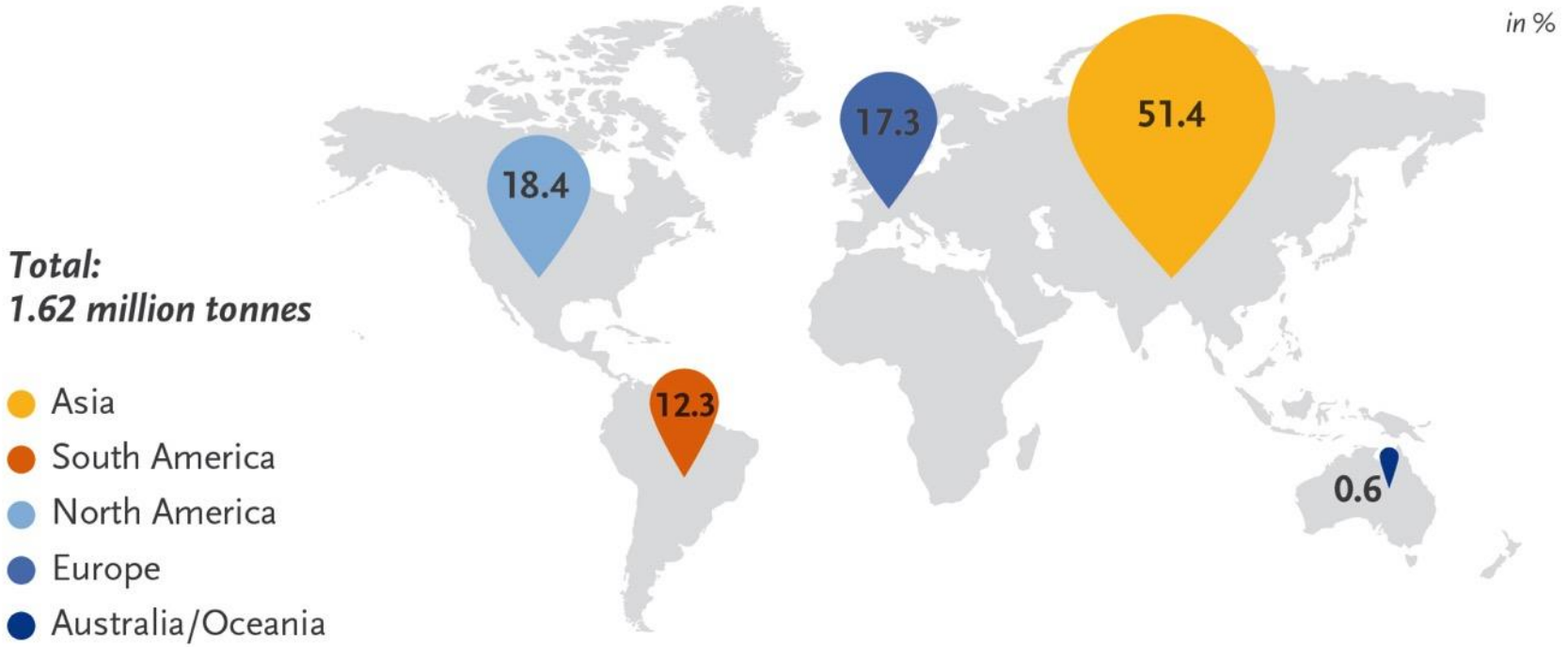
- Polyurethanes (PUR)
- Epoxies
- Ethylene Propylene Diene Monomer Rubber (EPDM)
- Cellulose acetate (CA)

Thermosets

# Production capacities grow > 350% between 2014-2019

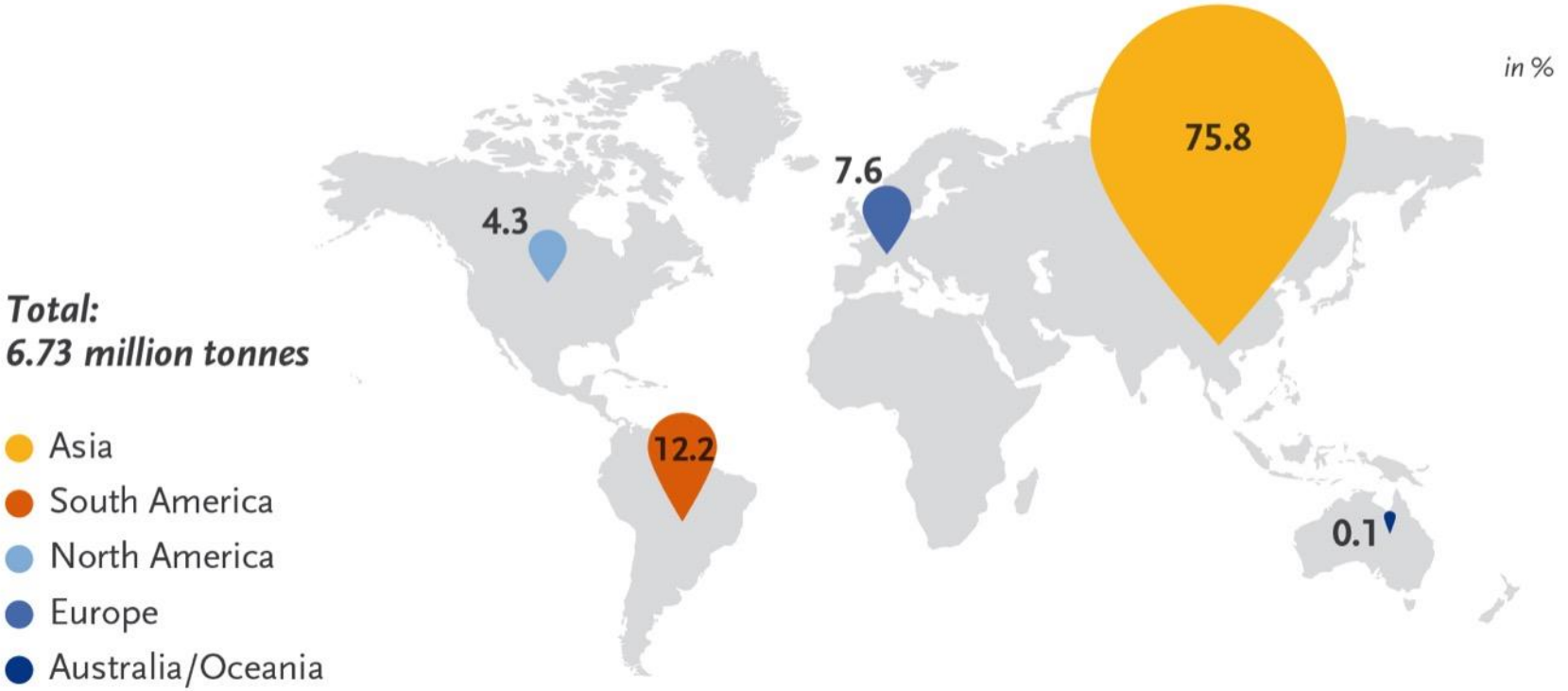


# Regional development of production capacities 2013




*Source: European Bioplastics, Institute for Bioplastics and Biocomposites, nova-Institute (2014).*
*More information:* ***www.bio-based.eu/markets*** *and* ***www.downloads.ifbb-hannover.de***

# Regional development of production capacities 2018




*Source: European Bioplastics, Institute for Bioplastics and Biocomposites, nova-Institute (2014).*
*More information:* ***www.bio-based.eu/markets*** *and* ***www.downloads.ifbb-hannover.de***

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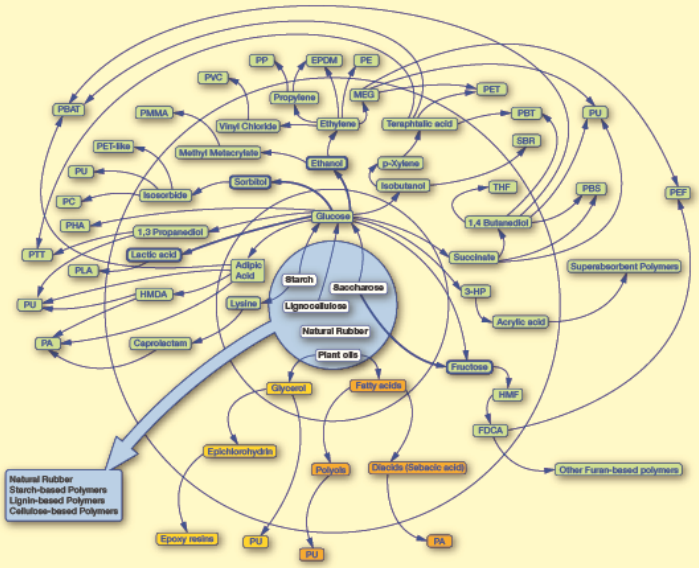
**3,000 €**

## Bio-based Building Blocks and Polymers in the World

Capacities, Production and Applications: Status Quo and Trends towards 2020




*Florence Aeschelmann, Michael Carus, Achim Raschka, Jan Ravenstijn, Wolfgang Baltus, Harald Käb, Howard Blum, Rainer Busch, Dirk Carrez, James Philp, Constance Ißbrücker, Stefan Zepnik*

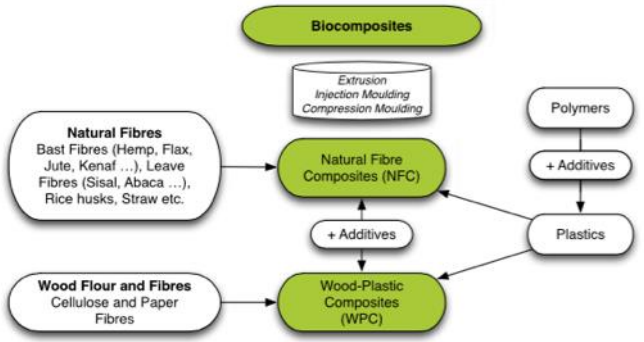
**1,000 €**

Short Version

WPC/NFC Market Study 2014-10 (Update 2015-06)

## Wood-Plastic Composites (WPC) and Natural Fibre Composites (NFC):

European and Global Markets 2012 and Future Trends in Automotive and Construction




*Authors: Michael Carus, Dr. Asta Eder, Lara Dammer, Dr. Hans Korte, Lena Scholz, Roland Essel, Elke Breitmayer, Martha Barth*

*First version 2014-03, Update 2015-06*

Download this study and further nova market studies at:
**www.bio-based.eu/markets**

Short versions can be downloaded at: [www.bio-based.eu/markets/](www.bio-based.eu/markets/)

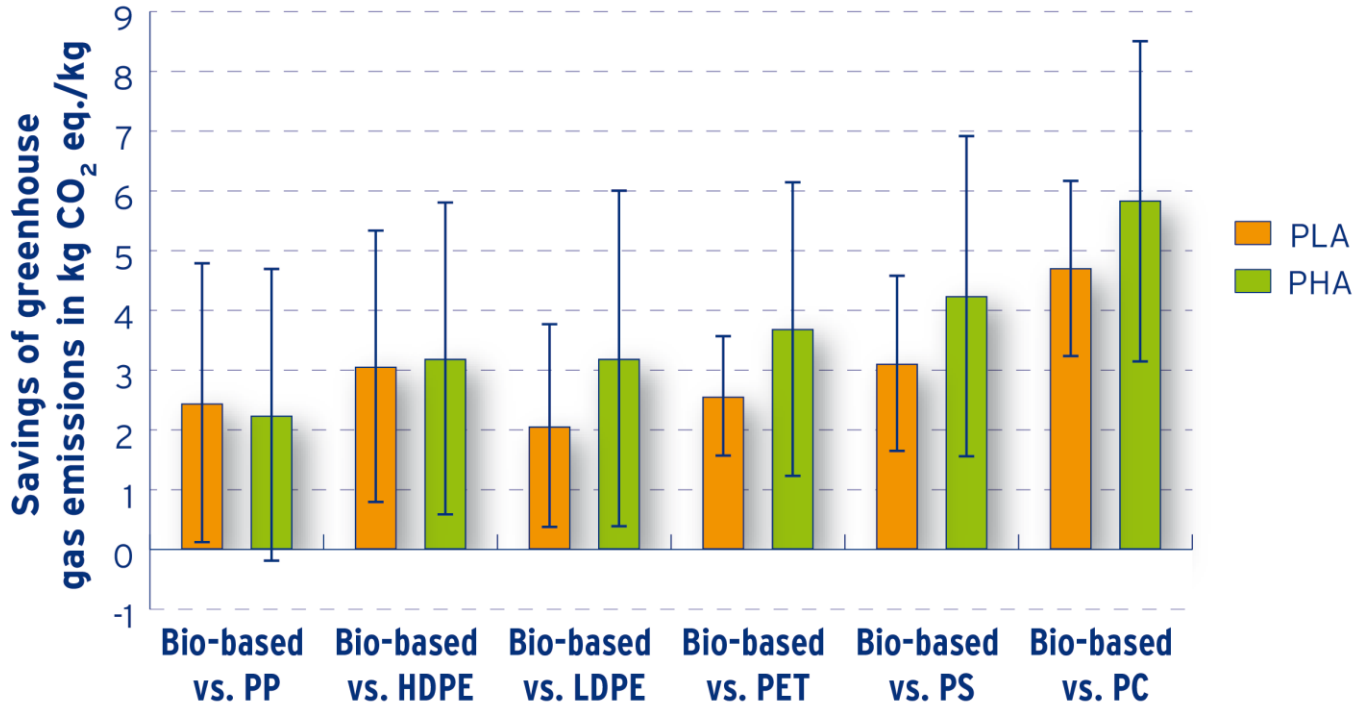
# Production of Biocomposites (WPC and NFC) in the European Union 2012 (in tonnes)

| | |
|---|---|
| **Wood-Plastic Composites** | **260,000** |
| Decking | 174,000 |
| Automotive | 60,000 |
| Siding and Fencing | 16,000 |
| Technical Applications | 5,000 |
| Furniture | 2,500 |
| Consumer goods | 2,500 |
| **Natural Fibre Composites** | **92,000** |
| Automotive | 90,000 |
| Others | 2,000 |
| **Total Volume Biocomposites (WPC and NFC)** | **352,000** |
| **Share** | **15 %** |
| Composite Production in European Union, total volume (Glass, Carbon, WPC and NFC) | 2.4 Million |

# Bio-based polymers
# &
# Environment

# Savings of greenhouse gases

## Savings of greenhouse gas emissions due to the production of bio-based polymers



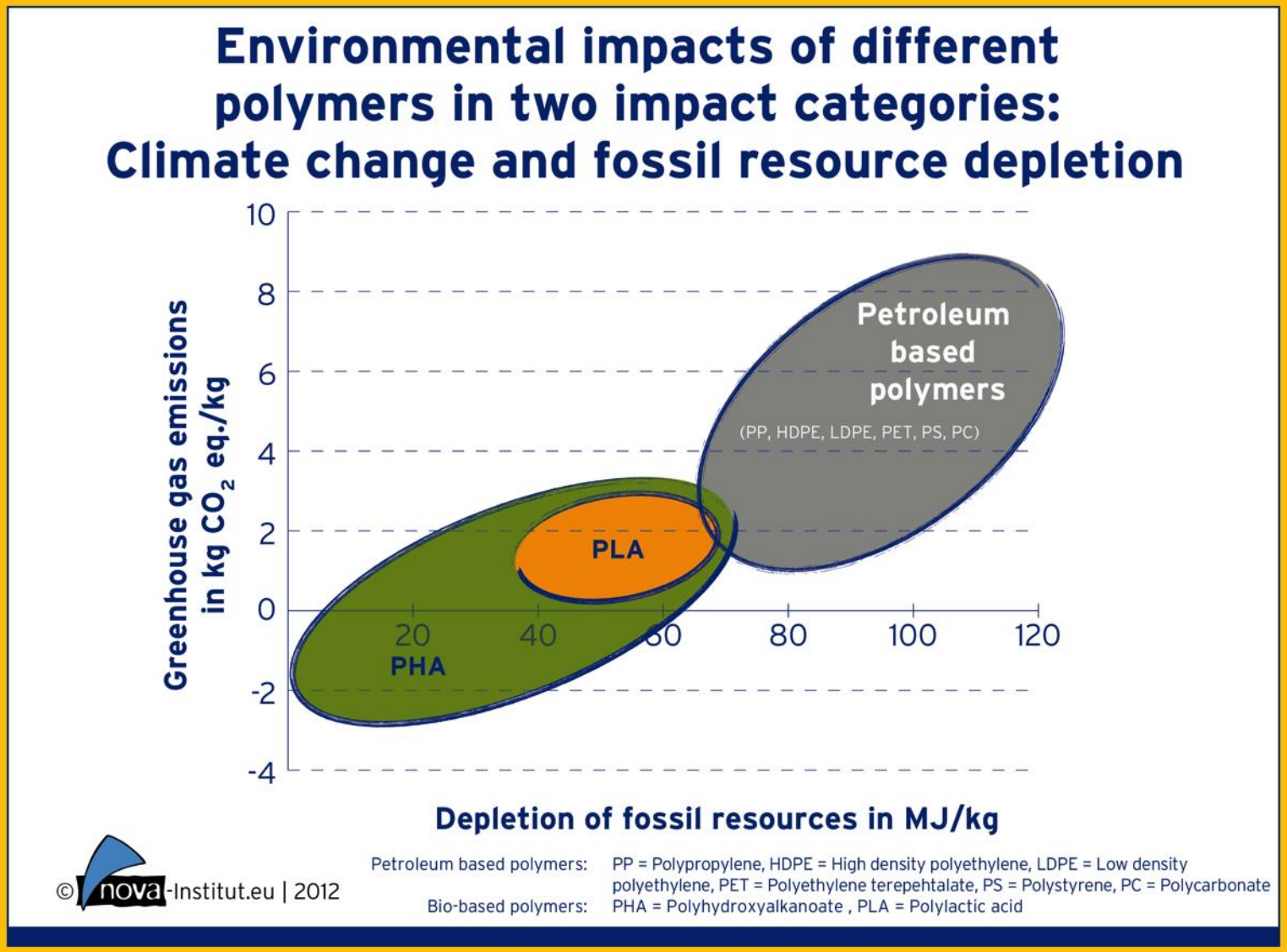

1. Bars indicate average values 2. Whiskers indicate standard deviation
3. Negative values indicate additional emissions of greenhouse gases



Petroleum based polymers: PP = Polypropylene, HDPE = High density polyethylene, LDPE = Low density polyethylene, PET = Polyethylene terepehtalate, PS = Polystyrene, PC = Polycarbonate

Bio-based polymers: PLA = Polylactic acid, PHA = Polyhydroxyalkanoate

# LCA results


Environmental impacts of different polymers in two impact categories: Climate change and fossil resource depletion
Greenhouse gas emissions in kg $CO_2$ eq./kg
10
8
6
4
2
0
-2
-4
20
40
60
80
100
120
Petroleum based polymers
(PP, HDPE, LDPE, PET, PS, PC)
PLA
PHA
Depletion of fossil resources in MJ/kg
© nova-Institut.eu | 2012
Petroleum based polymers: PP = Polypropylene, HDPE = High density polyethylene, LDPE = Low density polyethylene, PET = Polyethylene terepehtalate, PS = Polystyrene, PC = Polycarbonate
Bio-based polymers: PHA = Polyhydroxyalkanoate , PLA = Polylactic acid

# Sources of microplastics

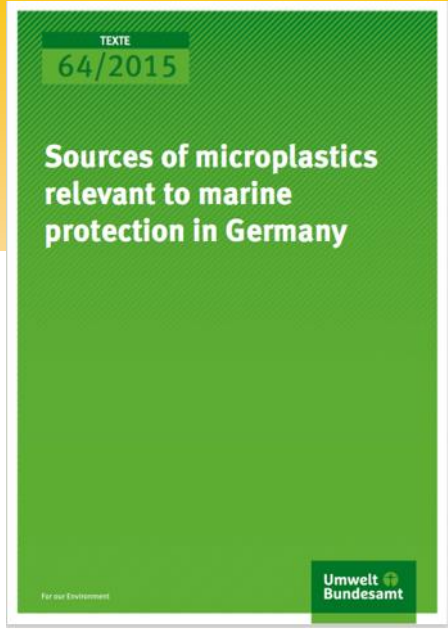
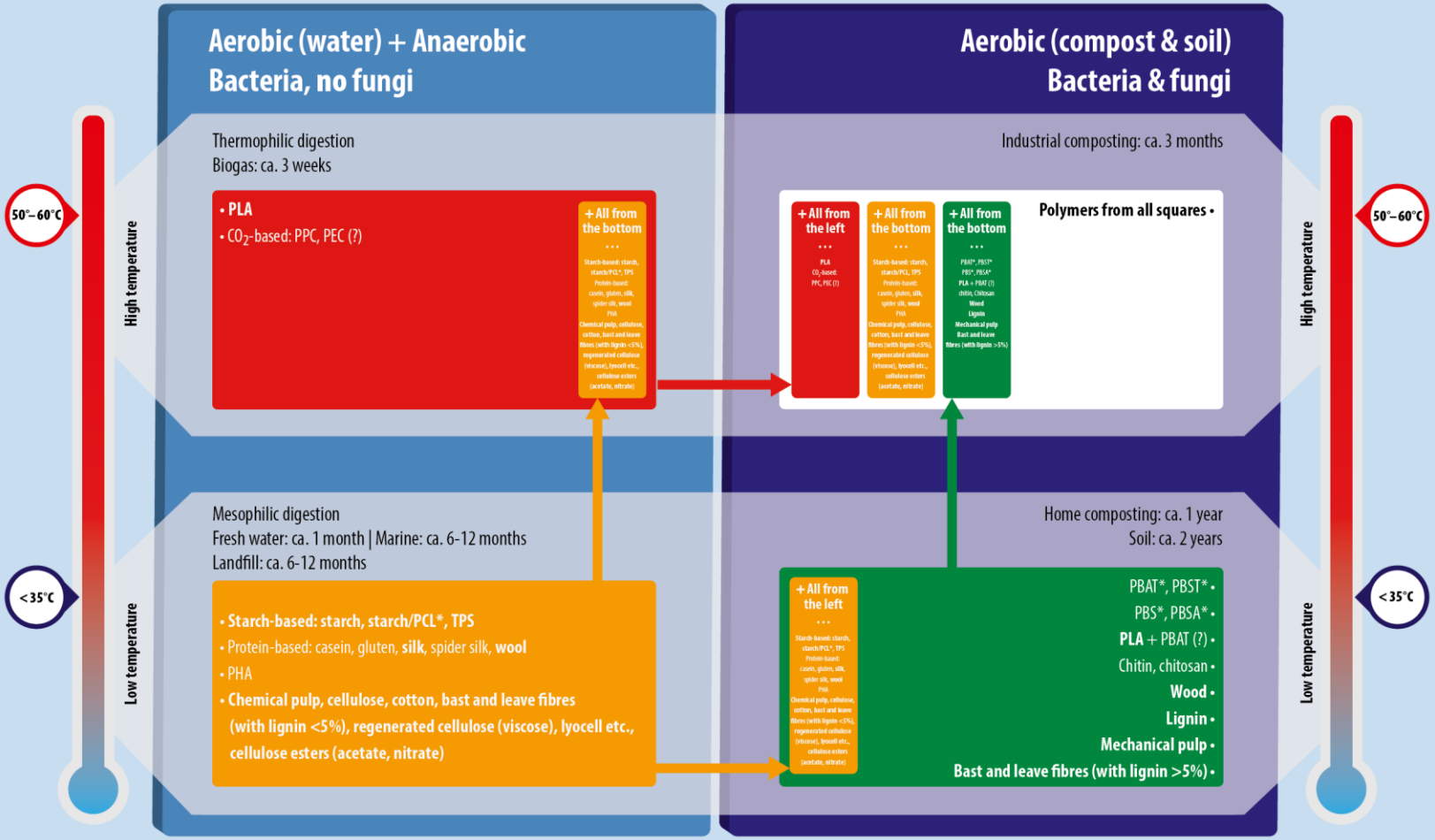



Table 7 Sources of primary and secondary microplastics in Germany (Source: Authors' own table)

| Sources of microplastics in Germany | Quantity of sources in tonnes of microplastics per year |
|---|---|
| Primary microplastics | |
| ▪ cosmetic products | 500 |
| ▪ detergents, cleaning and maintenance products for commercial and industrial use | < 100 |
| ▪ blasting abrasives for deburring surfaces | < 100 |
| ▪ Micronised synthetic waxes in technical applications | 100,000 |
| Secondary microparticles | |
| ▪ fragmentation of plastic debris | unknown |
| ▪ synthetic fibres from clothing and other textiles | 80 to 400 |
| ▪ pellet loss during manufacture and processing of plastics | 21,000 to 210,000 |
| ▪ tyre abrasion | 60,000 to 111,000 |

**Study free available: www.bio-based.eu**

# Biodegradable, bio-based polymers in various environments




Plastics derived from these biodegradable polymers only keep this property if also all additives and fillers are biodegradable, too.
**BOLD:** Bio-based polymers with relevant production volumes in 2014 (>10,000 t/year)
*: PBS, PBST, PBSA and PBAT so far mainly petro-based, but in the future bio-based; PCL so far only petro-based. ?: Not finally confirmed, further testing necessary.

**Free poster available: www.bio-based.eu**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Your feedback ist welcome: **michael.carus@nova-institut.de**
www.bio-based.eu


# Aerobic (water) + Anaerobic Bacteria, no fungi

Mesophilic digestion
Fresh water: ca. 1 month | Marine: ca. 6-12 months
Landfill: ca. 6-12 months

- **Starch-based: starch, starch/PCL*, TPS**
- Protein-based: casein, gluten, **silk**, spider silk, **wool**
- PHA
- **Chemical pulp, cellulose, cotton, bast and leave fibres (with lignin <5%), regenerated cellulose (viscose), lyocell etc., cellulose esters (acetate, nitrate)**




# Aerobic (compost & soil)
# Bacteria & fungi

Home composting: ca. 1 year
Soil: ca. 2 years

**+ All from the left**
...

**Starch-based: starch, starch/PCL*, TPS**
Protein-based: casein, gluten, **silk**, spider silk, **wool**
PHA
**Chemical pulp, cellulose, cotton, bast and leave fibres (with lignin <5%), regenerated cellulose (viscose), lyocell etc., cellulose esters (acetate, nitrate)**

PBAT*, PBST* •
PBS*, PBSA* •
**PLA** + PBAT (?) •
Chitin, chitosan •
**Wood** •
**Lignin** •
**Mechanical pulp** •
**Bast and leave fibres (with lignin >5%)** •

**Low temperature**


# Aerobic (water) + Anaerobic
# Bacteria, no fungi

Thermophilic digestion
Biogas: ca. 3 weeks

- **PLA**
- $CO_2$-based: PPC, PEC (?)

**+ All from the bottom**

...

**Starch-based: starch, starch/PCL®, TPS**
Protein-based: casein, gluten, **silk**, spider silk, **wool**
PHA
**Chemical pulp, cellulose, cotton, bast and leave fibres (with lignin <5%), regenerated cellulose (viscose), lyocell etc., cellulose esters (acetate, nitrate)**



# Aerobic (compost & soil)
# Bacteria & fungi

Industrial composting: ca. 3 months

**+ All from the left**

...

**PLA**
$CO_2$-based:
PPC, PEC (?)

**+ All from the bottom**

...

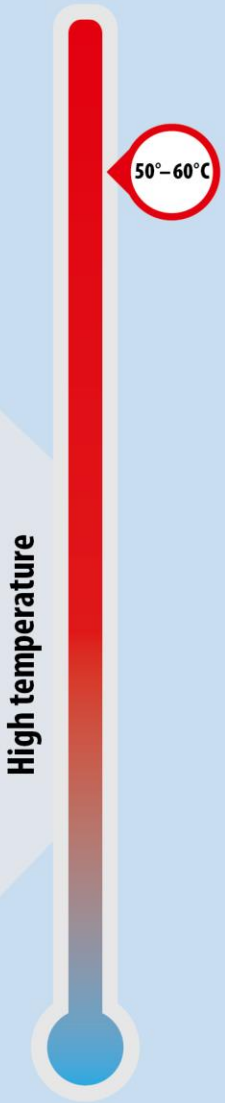
**Starch-based: starch, starch/PCL, TPS**
Protein-based:
casein, gluten, **silk**, spider silk, **wool**
PHA
**Chemical pulp, cellulose, cotton, bast and leave fibres (with lignin <5%), regenerated cellulose (viscose), lyocell etc., cellulose esters (acetate, nitrate)**

**+ All from the bottom**

...

PBAT*, PBST*
PBS*, PBSA*
**PLA** + PBAT (?)
chitin, Chitosan
**Wood**
**Lignin**
**Mechanical pulp**
**Bast and leave fibres (with lignin >5%)**

**Polymers from all squares •**

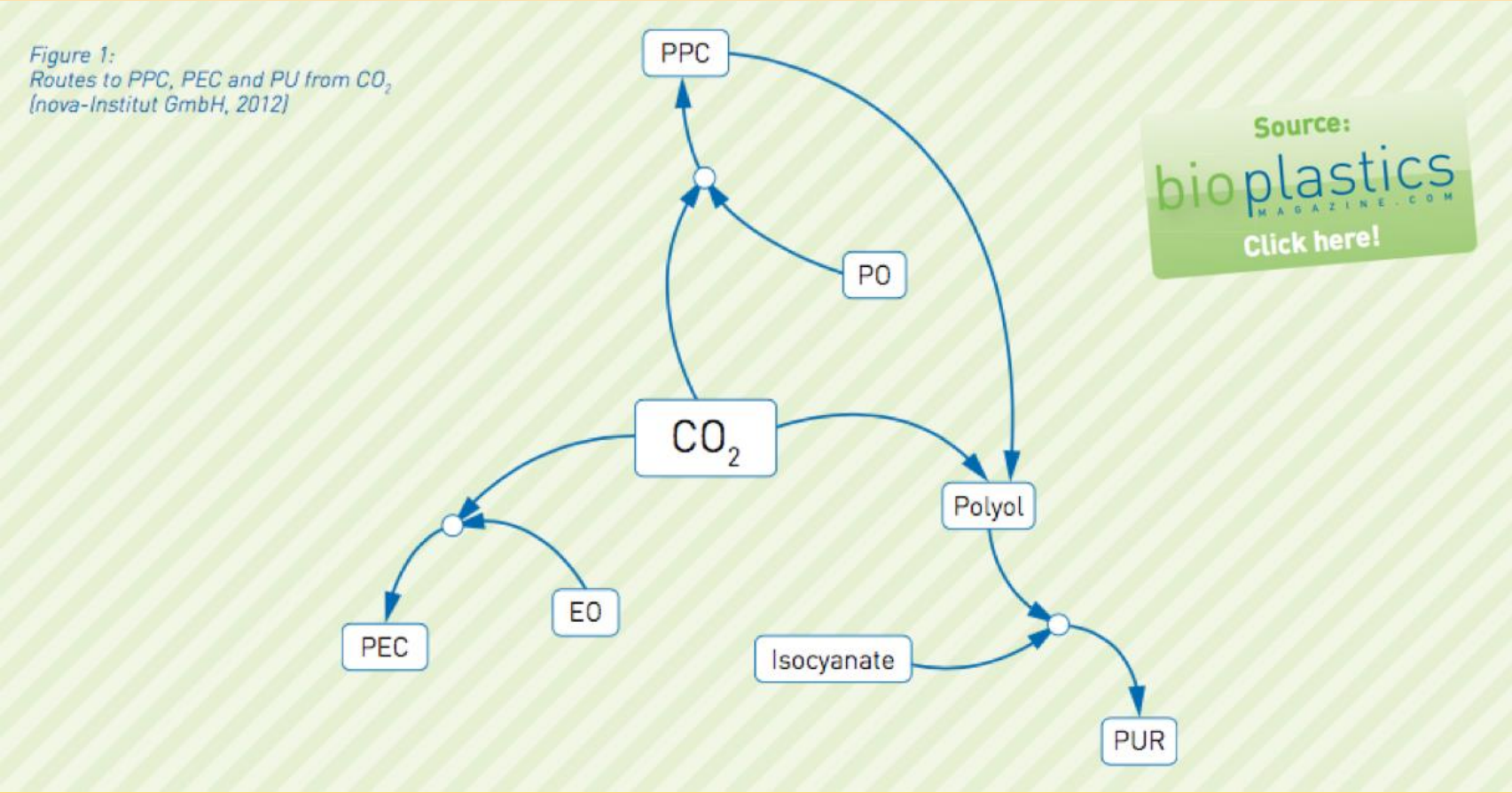


Basics

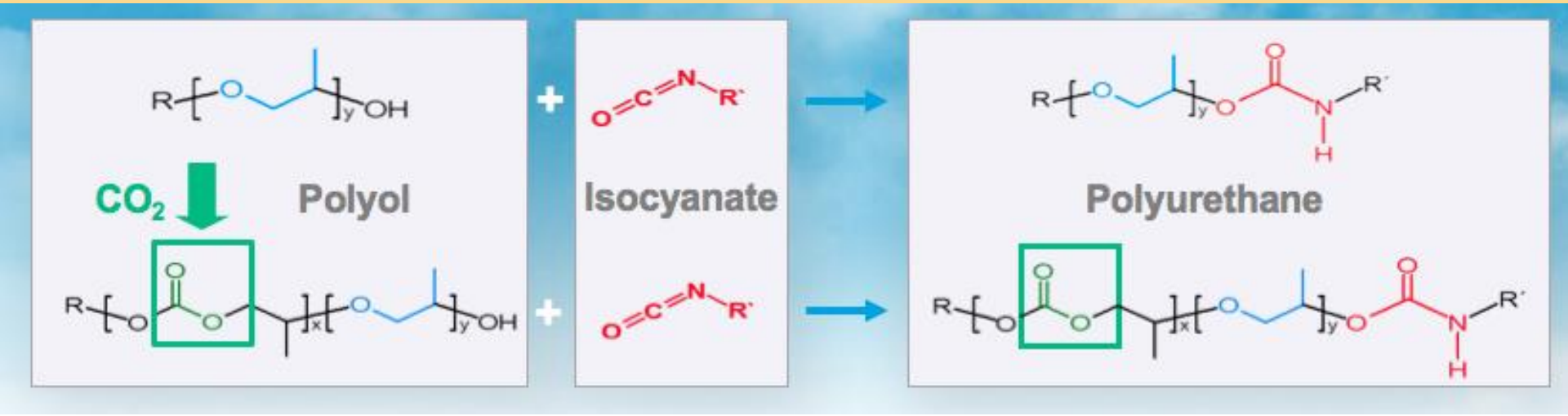
# Plastics made from $CO_2$

## Carbon dioxide as chemical feedstock

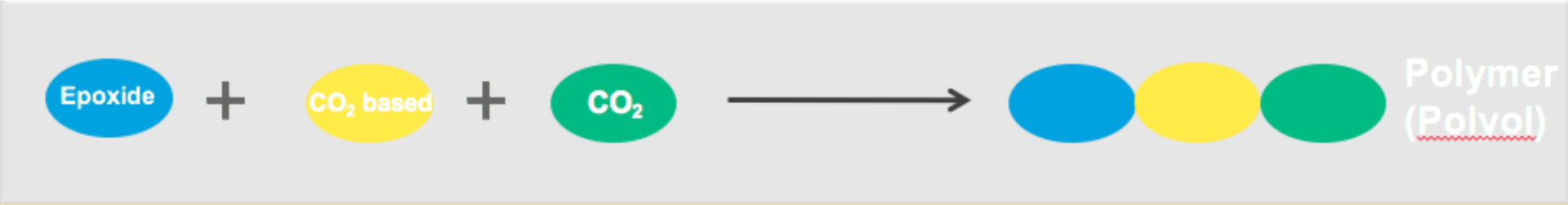
# Polypropylene carbonates (PPC) and Polyenthylen carbonates (PEC) via $CO_2$ and propylene oxid / ethylene oxid – and via $CO_2$ , Polyol and Isoccyanate to PUR



# Dream Polymers: Polyurethanes

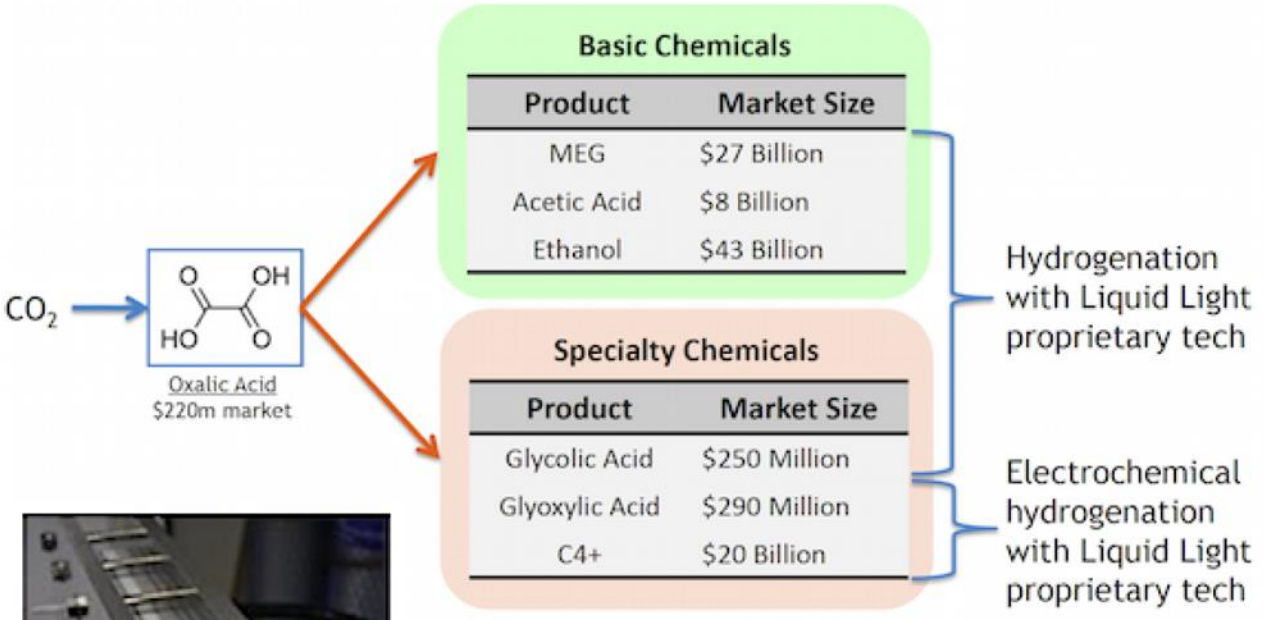


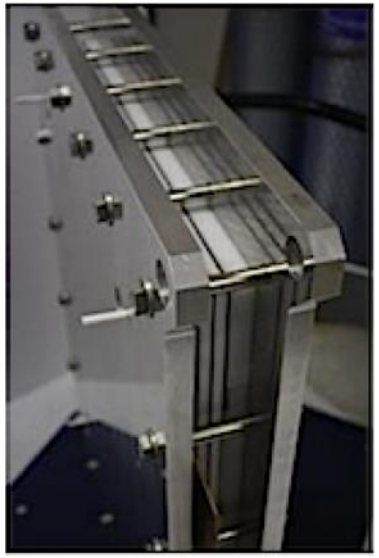

## Next generation Polyols




$CO_2$-based
Methanol

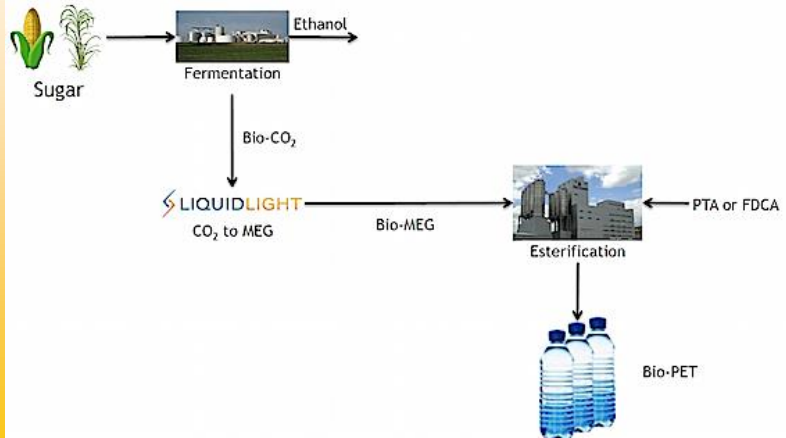
# Oxalic acid / Bio-PET



LIQUIDLIGHT

Why customers care, part 2:
With LL: bio-PET less expensive to make; ethanol producers increase revenue; consumers get more sustainable products



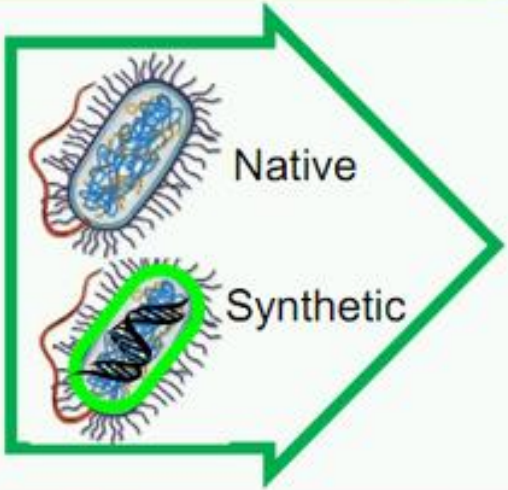
# LanzaTech Gas to Liquid Platform

LanzaTech

**Resources**

- CO — Industrial
- CO / $H_2$ — Syngas: Biomass, Coal, Methane
- $H_2$ / $CO_2$ — COG, Chemical
- $CO_2$ — Power

**Customized Catalysts**



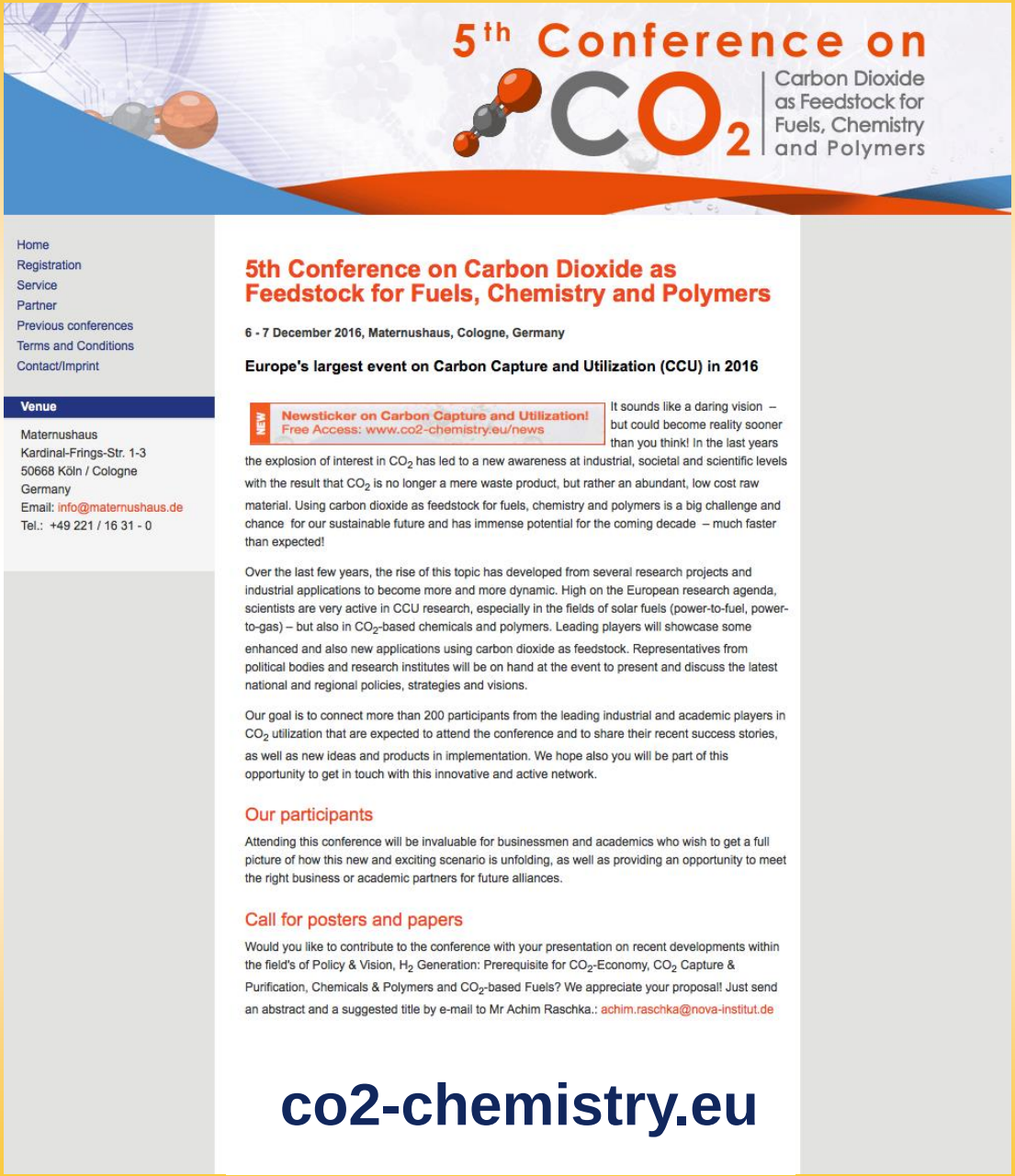

Engineering
Control
Chemistry

**Product Suite**

| $C_2$ | $C_3$ | $C_4$ | $C_5$ | Other |
|---|---|---|---|---|
| • Ethanol<br>• Acetic acid | • *i*-propanol | • BDO<br>• *n*-Butanol<br>• *i*-Butanol<br>• Succinic acid | • Isoprene | • PHB<br>• ……. |

**Product Suite** — *Thermochemical Approaches*

- Hydrocarbon Fuels (diesel, jet, gasoline)
- Chemical Intermediates
- Olefins
- Chemicals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NEW
Newsticker on Carbon Capture and Utilization!
Free Access: www.co2-chemistry.eu/news
It sounds like a daring vision – but could become reality sooner than you think! In the last years the explosion of interest in CO2 has led to a new awareness at industrial, societal and scientific levels with the result that CO2 is no longer a mere waste product, but rather an abundant, low cost raw material. Using carbon dioxide as feedstock for fuels, chemistry and polymers is a big challenge and chance for our sustainable future and has immense potential for the coming decade – much faster than expected!
Over the last few years, the rise of this topic has developed from several research projects and industrial applications to become more and more dynamic. High on the European research agenda, scientists are very active in CCU research, especially in the fields of solar fuels (power-to-fuel, power-to-gas) – but also in CO2-based chemicals and polymers. Leading players will showcase some enhanced and also new applications using carbon dioxide as feedstock. Representatives from political bodies and research institutes will be on hand at the event to present and discuss the latest national and regional policies, strategies and visions.
Our goal is to connect more than 200 participants from the leading industrial and academic players in CO2 utilization that are expected to attend the conference and to share their recent success stories, as well as new ideas and products in implementation. We hope also you will be part of this opportunity to get in touch with this innovative and active network.
Our participants
Attending this conference will be invaluable for businessmen and academics who wish to get a full picture of how this new and exciting scenario is unfolding, as well as providing an opportunity to meet the right business or academic partners for future alliances.
Call for posters and papers
Would you like to contribute to the conference with your presentation on recent developments within the field's of Policy & Vision, H2 Generation: Prerequisite for CO2-Economy, CO2 Capture & Purification, Chemicals & Polymers and CO2-based Fuels? We appreciate your proposal! Just send an abstract and a suggested title by e-mail to Mr Achim Raschka.: achim.raschka@nova-institut.de
co2-chemistry.eu


9th International Conference on Bio-based Materials
5 – 6 April 2016, Maternushaus, Cologne, Germany
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Special Topics: ++ Lignin ++ Polyhydroxyalkanoates (PHA) ++ Innovation Award "Bio-based Material of the Year 2016"
NEW Press release: Looking for the "Bio-based Material of the Year 2016" ++ over 60 participants registered ++
Highlights of the worldwide Bioeconomy: Policy and Markets – Bio-based Building Blocks and Polymers – Biorefineries and Industrial Biotechnology
This conference aims to provide international major players from the bio-based building blocks, polymers and industrial biotechnology industries with an opportunity to present and discuss their latest developments and strategies. Representatives of political bodies and associations will also have their say alongside leading companies. The 9th International Conference on Bio-based Materials builds on successful previous conferences. 250 participants and 30 exhibitors mainly from industry are expected!
Register now!
Free booths!
Exhibition booths are free for registered participants! Please contact Dominik Vogt, dominik.vogt@nova-institut.de
Innovation Award "Bio-based Material of the Year 2016"
For the ninth year running, the Innovation Award "Bio-based Material of the Year" will be granted to the young, innovative bio-based chemicals and materials industry for finding suitable applications and markets for bio-based products. The focus of the award is on new developments within these areas, which had been launched in 2015 or will be launched in 2016.
Don't miss this opportunity!
Take part in the conference and benefit from a 30% discount on the registration fee of the Bio-based Start-up Day (7 April 2016)!
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# Thank you for your attention!


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