# Market Data and Trends for "Bio-based Building Blocks and Polymers"

Nova-Institute

Wageningen University & Research

19 October 2021, ONLINE

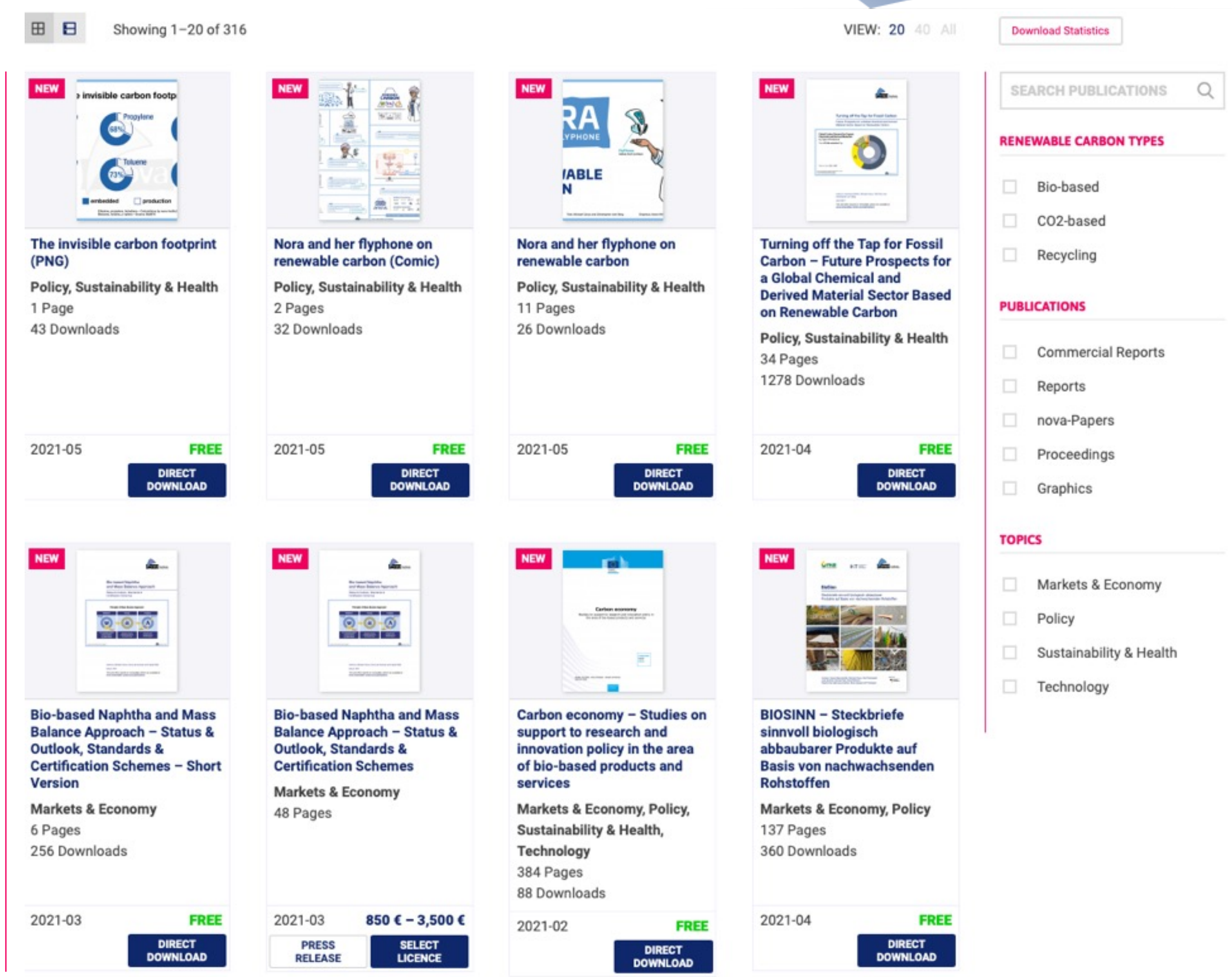
Pauline Ruiz, nova-Institute

nova provides studies on all renewable carbon relevant topics such as **bio-based & $CO_2$-based polymers as well as chemical recycling**

# Renewable Carbon Publications

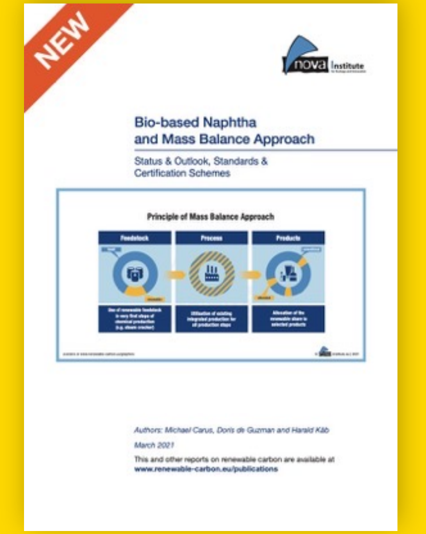
Over 300 publications on bio-based, $CO_2$-based and recycling by nova-institute

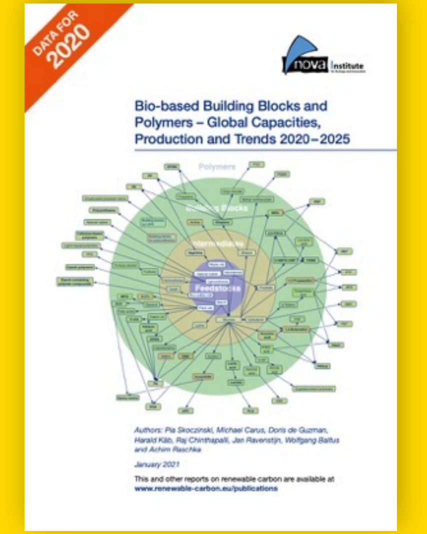
**www.renewable-carbon.eu/publications**

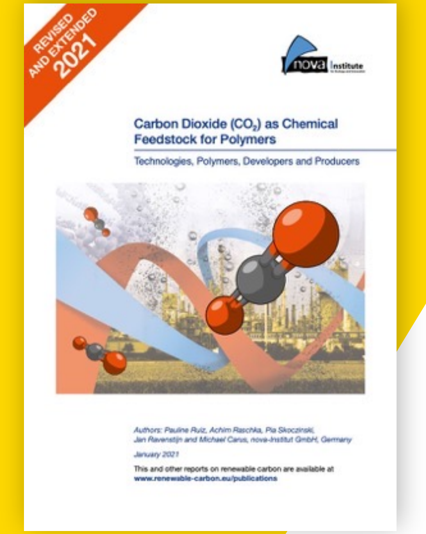


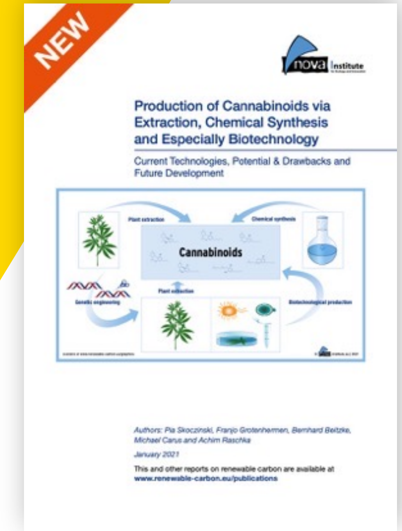

RENEWABLE CARBON **PUBLICATIONS**

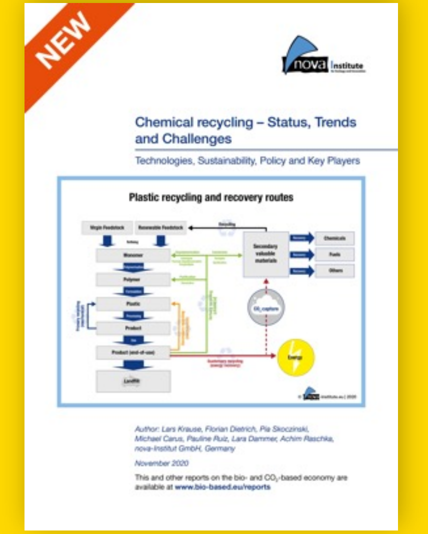
# Market and Trend Reports on Renewable Carbon



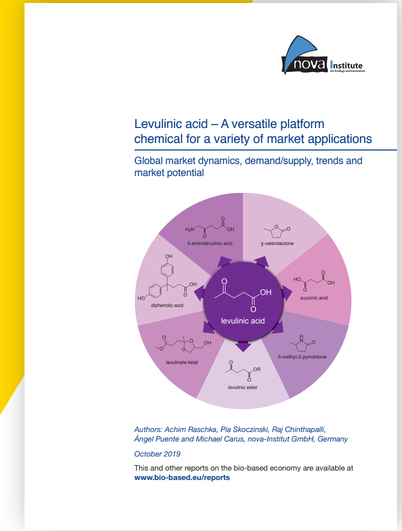



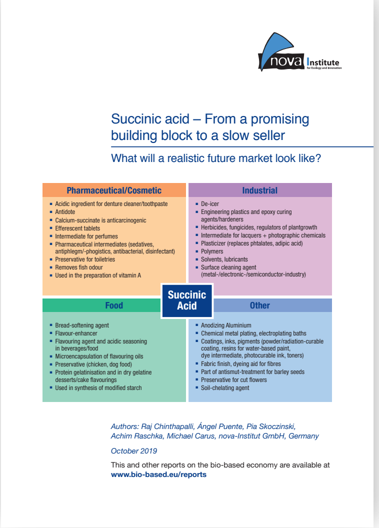








The Best Available on Bio- an $CO_2$-based Polymers & Building Blocks and Chemical Recycling

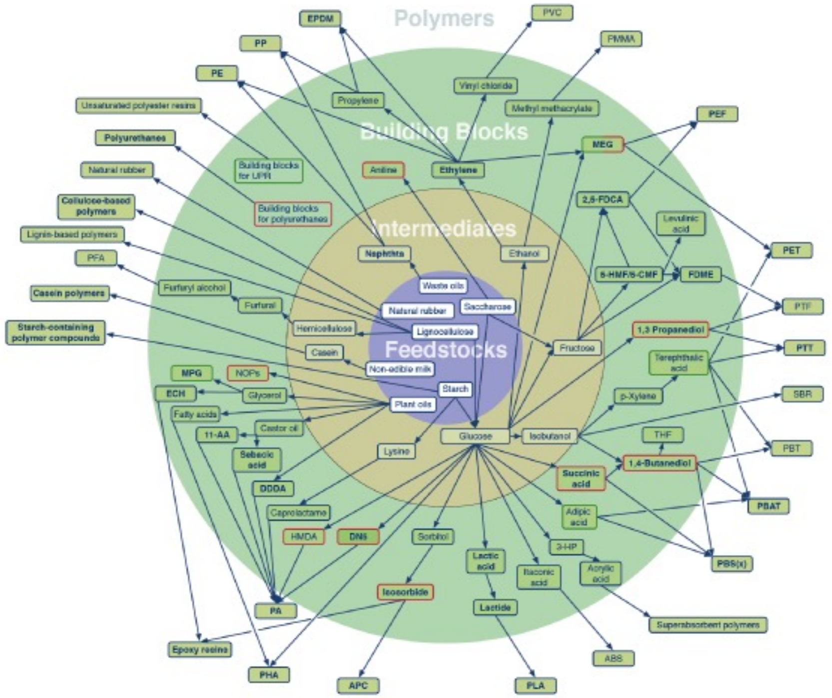
renewable-carbon.eu/publications

DATA FOR 2020

nova Institute for Ecology and Innovation

RENEWABLE CARBON renewable-carbon.eu

# Bio-based Building Blocks and Polymers – Global Capacities, Production and Trends 2020–2025




*Authors: Pia Skoczinski, Michael Carus, Doris de Guzman, Harald Käb, Raj Chinthapalli, Jan Ravenstijn, Wolfgang Baltus and Achim Raschka*

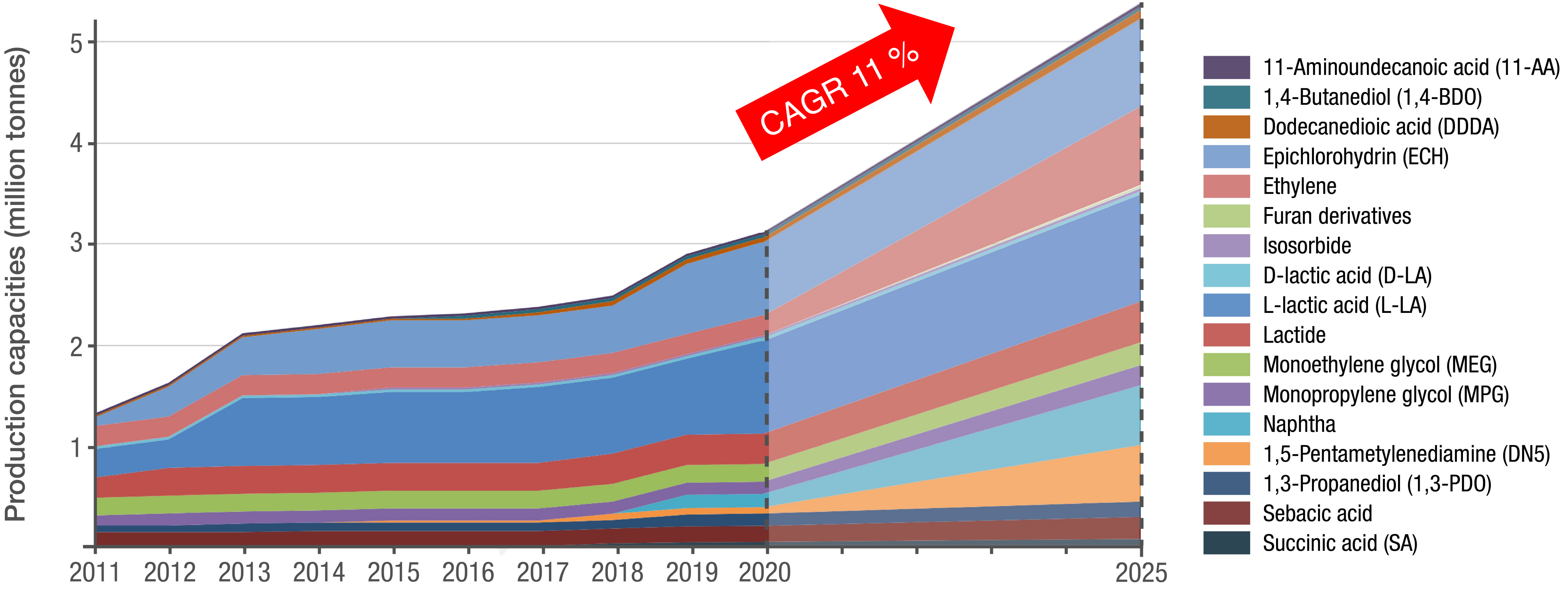
*January 2021*

This and other reports on renewable carbon are available at **www.renewable-carbon.eu/publications**


- Published in January 2021
- Data for 2020
- 338 pages
- 17 bio-based building blocks and 17 polymers
- 174 company profiles
- € 3,000 – www.renewable-carbon.eu/publications

# Bio-based Building Blocks

# Bio-based building blocks
# Evolution of worldwide production capacities from 2011 to 2025




available at www.renewable-carbon.eu/graphics

# Significant Findings from 2019 to 2020

Increase in production capacity of 212,000 tonnes from 2019 to 2020

- Asian expansion of **epichlorohydrin (ECH)** capacity
- Asian capacity increase of **D-/L-lactic acid**
- European capacity increase of **1,3-propanediol (1,3-PDO)**
- Asian increase in **succinic acid (SA)** capacity

# Significant Findings – Forecast 2020 to 2025

| | 2020 | 2025 |
|---|---|---|
| Capacity | 3.1 million tonnes | 5.4 million tonnes |

**Main drivers for capacity increase to 2025:**

- 11-Aminoundecanoic acid (11-AA)
- Dodecanedioic acid (DDDA)
- Ethylene
- **Furan derivatives:** 5-Chloromethylfurfural (5-CMF), 2,5-furandicarboxylic acid (2,5-FDCA), 5-hydroxymethylfurfural (5-HMF)
- **Monopropylene glycol (MPG)**
- Naphtha
- 1,5-Pentamethylenediamine (DN5)
- **Succinic acid (SA)**

# Furan derivatives

**5-Chloromethylfurfural (5-CMF), feedstock: fructose**

- Alternative for 2,5-FDCA and FDME synthesis via the instable 5-HMF
- Mainly used as an intermediate and raw material for the production of biofuels and bio-based PET
- Production is mainly in North America and Australia and expected for 2021/2022

**5-Hydroxymethylfurfural (5-HMF), feedstock: fructose**

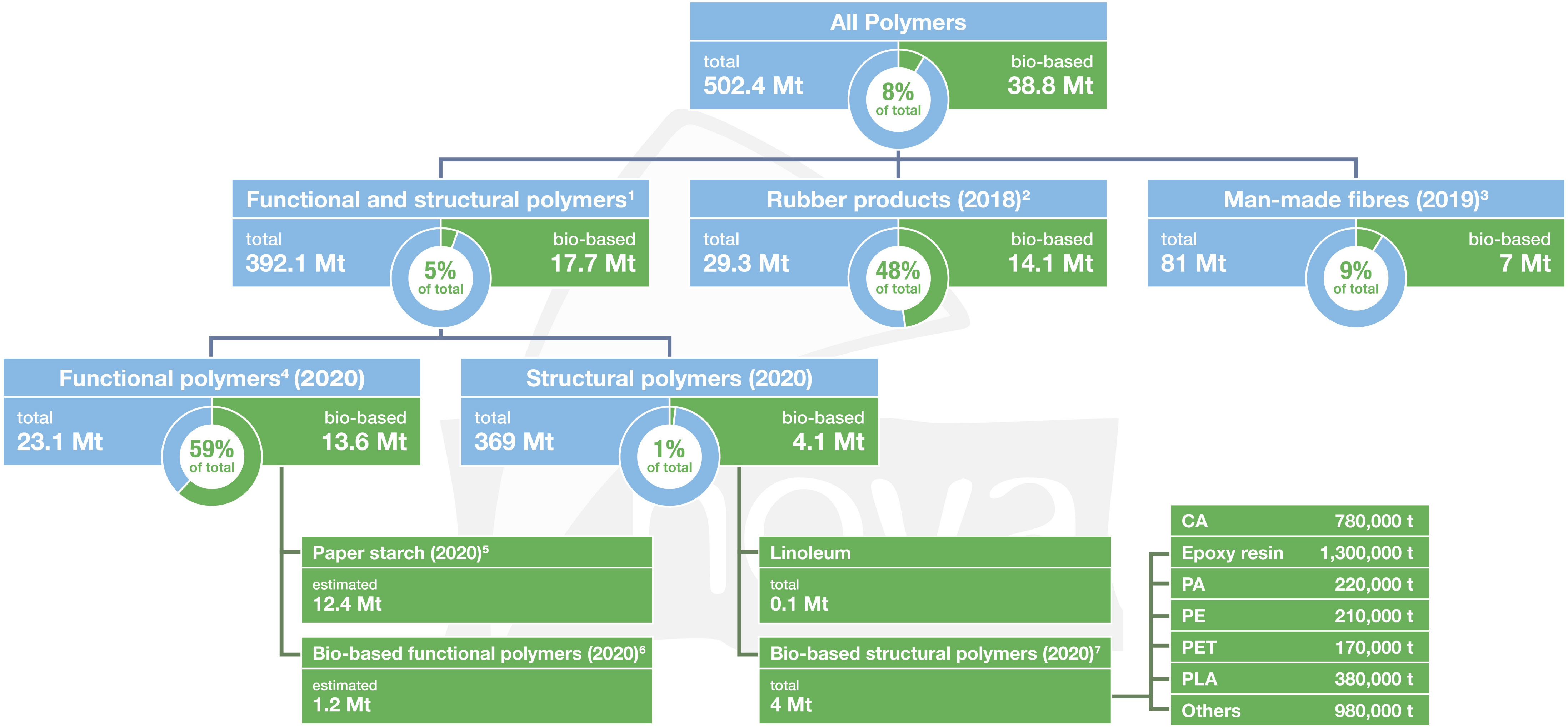
- Mainly used as the basis for 2,5-FDCA production
- Production is mainly in Europe, currently at demo scale, large scale production expected for 2025

**2,5-Furandicarboxylic acid (2,5-FDCA), feedstock: fructose**

- Most important application as a building block for the production of bio-based polyesters, polyamides, and polyurethanes
- Can potentially replace several chemicals as terephthalic acid (TPA), bisphenol A, adipic acid and phthalic anhydride
- Strong potential to be used in the production of solvents especially novel solvents
- Production is mainly in Europe, currently at demo scale, large scale production expected for 2023

# Bio-based Polymers

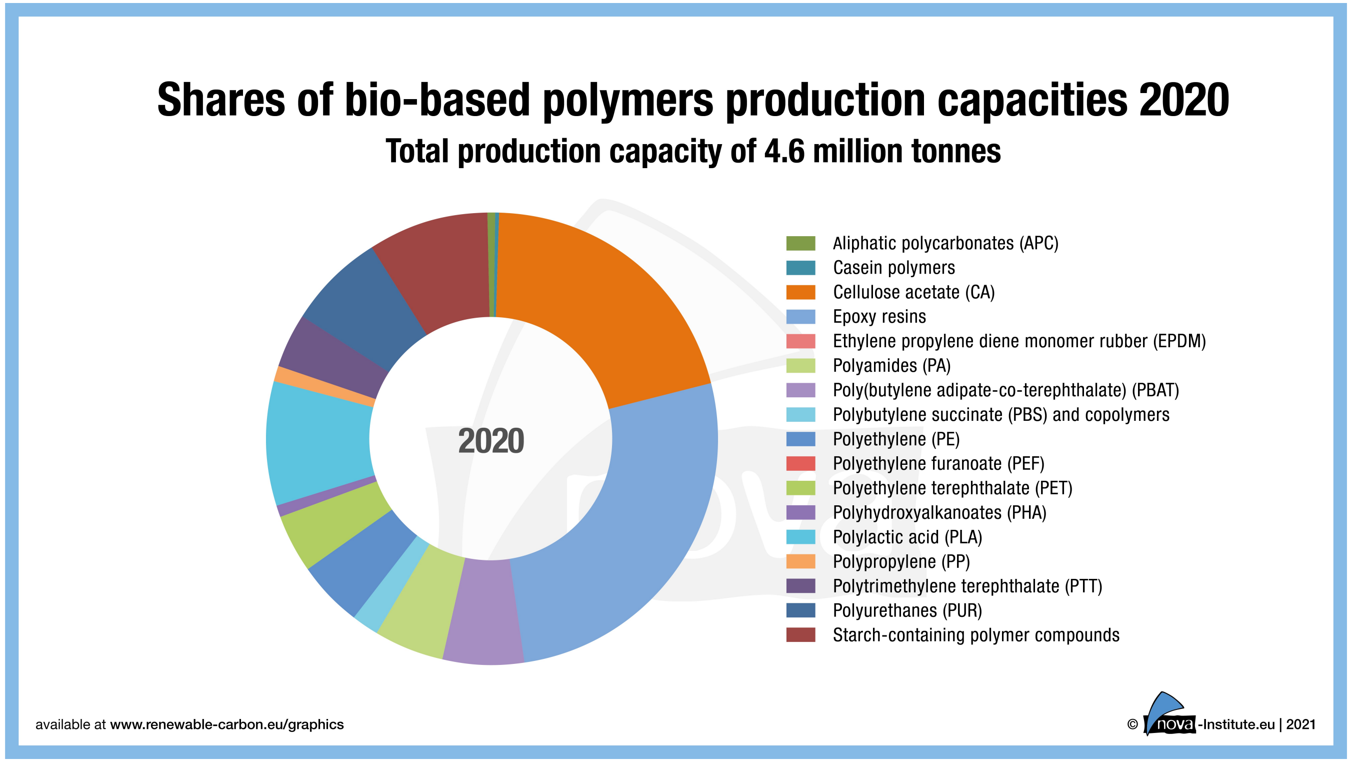
# Polymers worldwide, bio-based shares (2018-2020)

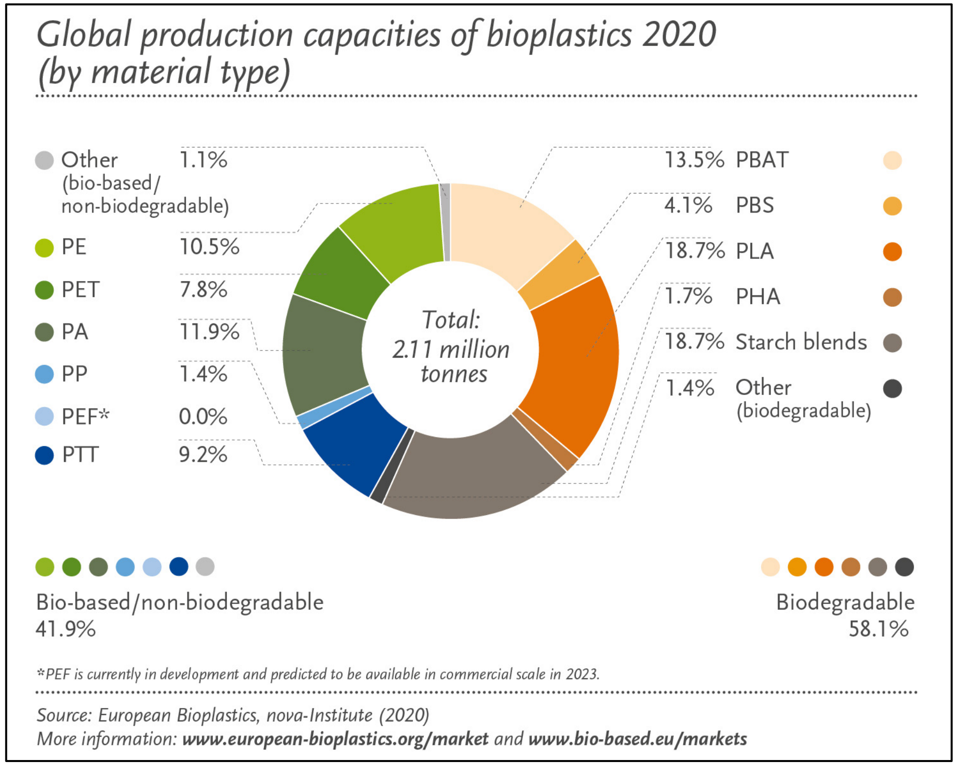



**Sources:** [1] Plastics Europe; [2] International Rubber Study Group (IRSG); [3] The Fiber Year 2020; [4] Calculations by nova-Institute based on different company and industry reports; [5] Calculations by nova-Institute based on CEPI, FAOSTAT, Starch Europe; [6] Calculations by nova-Institute based on different industry reports; [7] nova-Institute: Bio-based Building Blocks and Polymers – Global Capacities, Production and Trends 2020–2025, **www.bio-based.eu/reports**

available at
**www.renewable-carbon.eu/graphics**

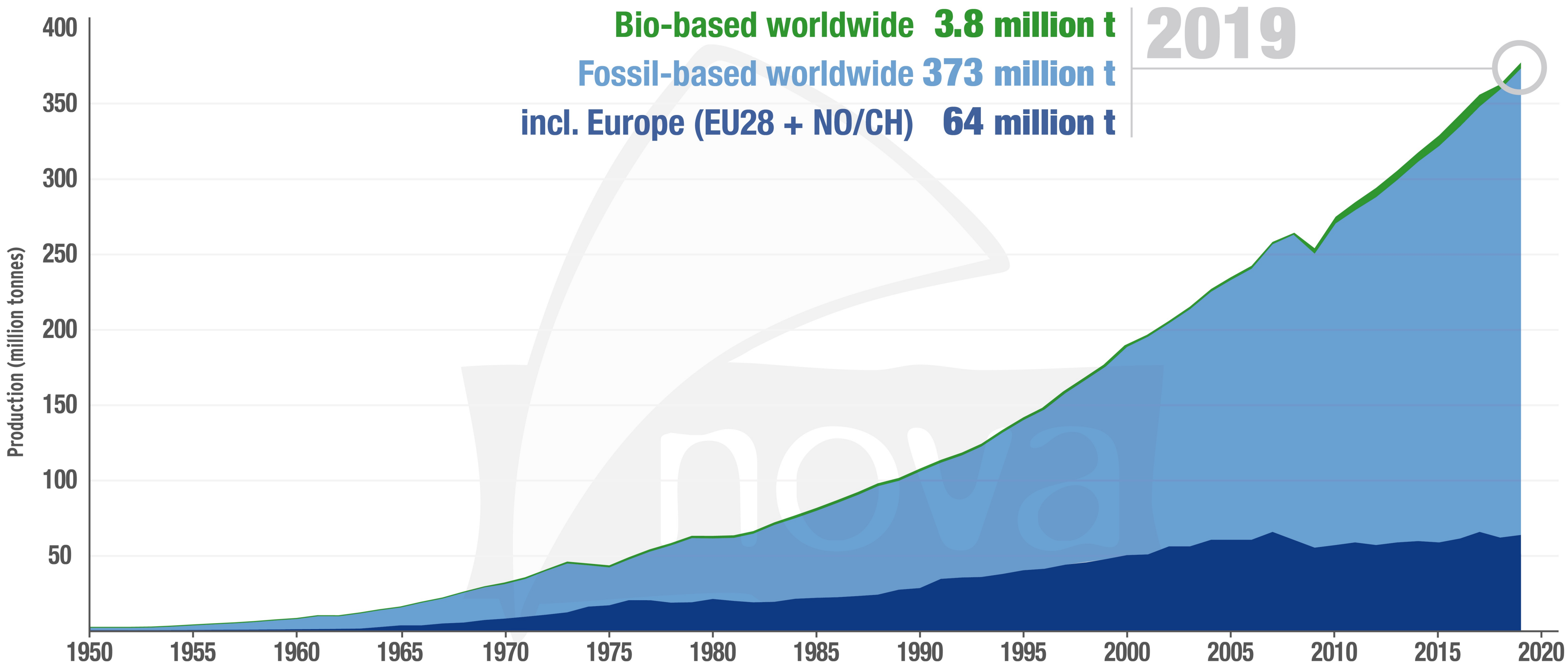
# Difference between nova and EUBP data




EUBP data does not include aliphatic polycarbonates (APC), casein polymers, cellulose acetate, epoxy resins, ethylene propylene diene monomer rubber (EPDM) and polyurethanes (PUR).

# Plastics production from 1950 to 2019

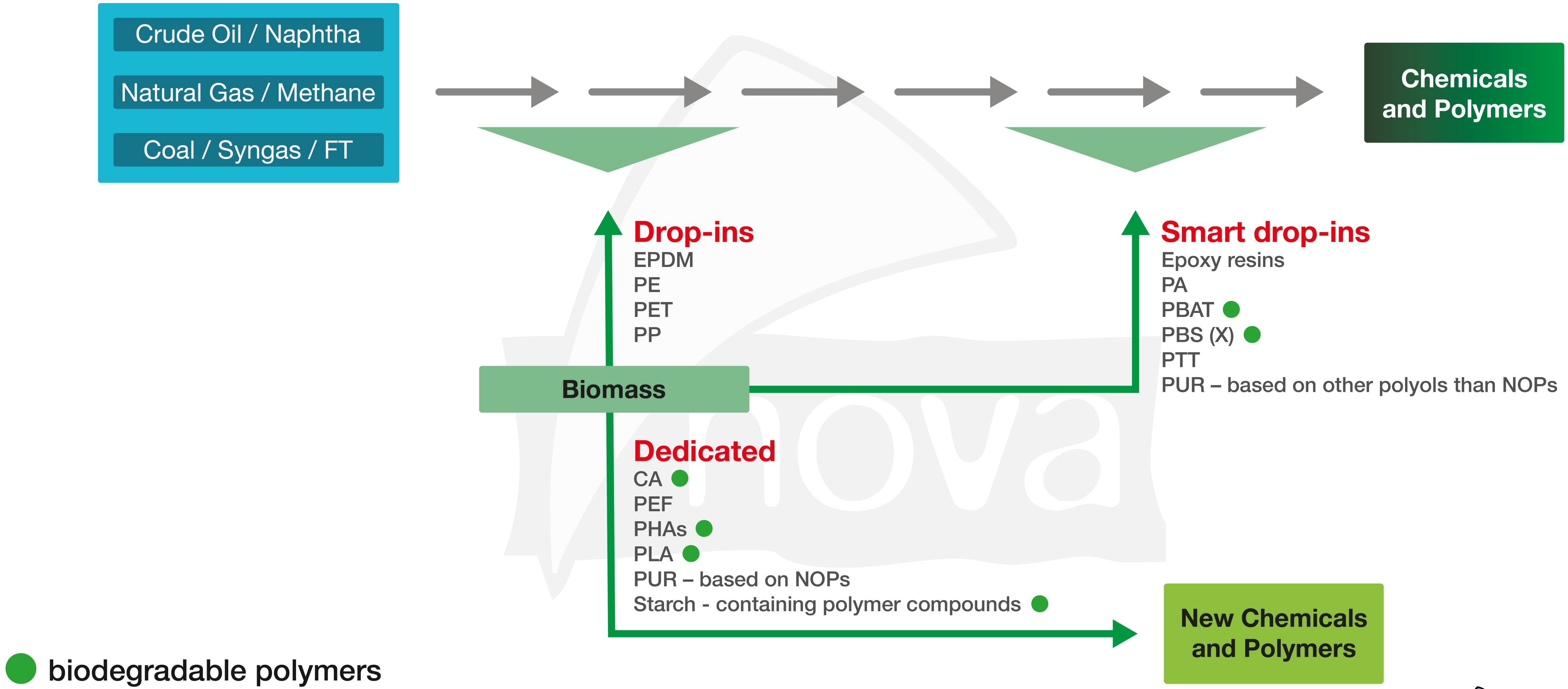



available at **www.renewable-carbon.eu/graphics**

Includes thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings and sealants and PP-fibres. Not included PET-, PA-, and polyacryl-fibres.

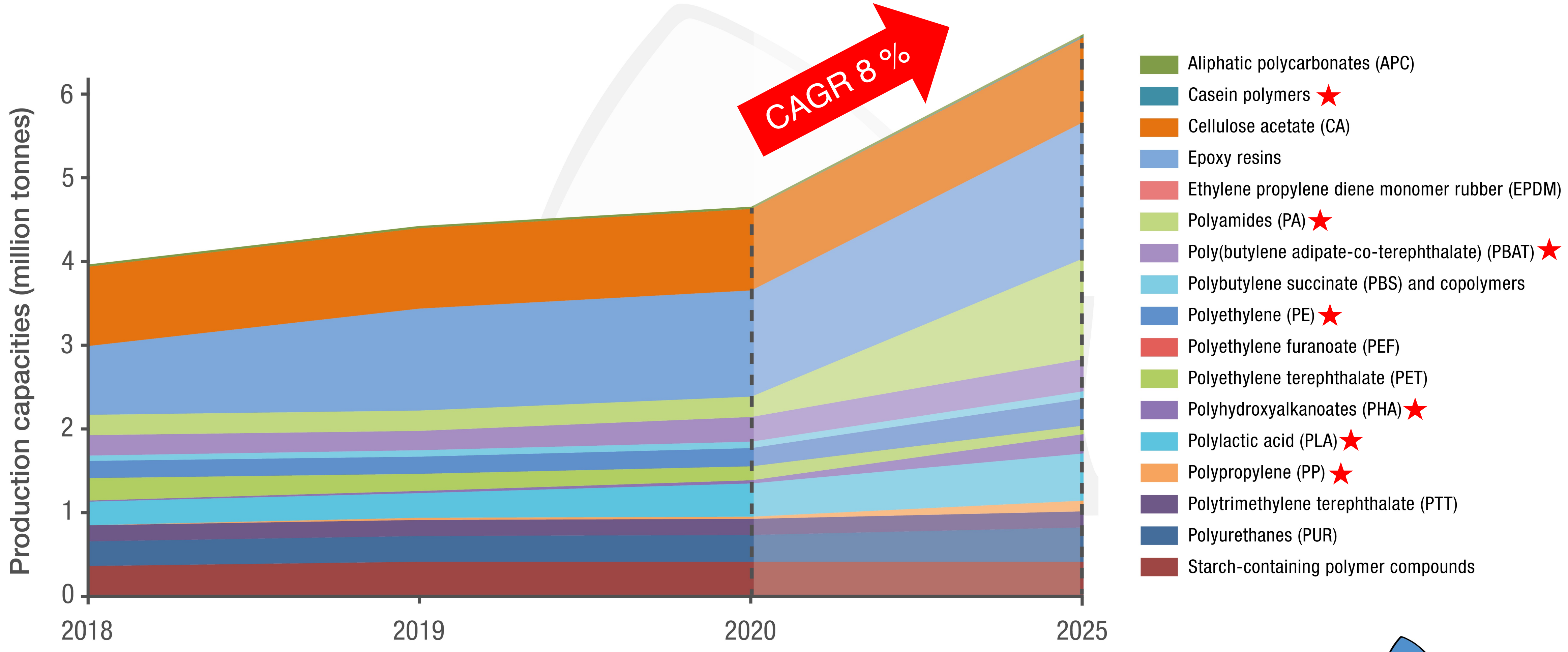
Data sources: PlasticsEurope, Consultic and nova-Institute

# Schematic differentiation of pathways of drop-in, smart drop-in and dedicated bio-based chemicals and polymers




available at www.renewable-carbon.eu/graphics

# Bio-based polymers
# Evolution of worldwide production capacities from 2018 to 2025




available at **www.renewable-carbon.eu/graphics**

# Significant Findings from 2019 to 2020

| | 2019 | 2020 |
|---|---|---|
| Capacity | 4.4 million tonnes | 4.6 million tonnes |
| Production | 3.9 million tonnes | 4.2 million tonnes |

Increase in production capacity of 229,000 tonnes from 2019 to 2020

- Asian expansion of **epoxy resin** production
- Increase in Asian capacity for **poly(butylene adipate-co- terephthalate) (PBAT)** and **polybutylene succinate (PBS)**
- European production increase for **polyethylene (PE)** and **polypropylene (PP)**
- Worldwide **PHA** capacity increase
- Asian expansion in **PLA** capacity

# Significant Findings – Forecast 2020 to 2025

| | 2020 | 2025 |
|---|---|---|
| Capacity | 4.6 million tonnes | 6.7 million tonnes |

**Main drivers for capacity increase to 2025:**

- **Casein polymers**
- **Polyamides (PA)**
- **Poly(butylene adipate-co- terephthalate) (PBAT)**
- **Polyethylene (PE)**
- Polyhydroxyalkanoates (PHA)
- **Polylactic acid (PLA)**
- **Polypropylene (PP)**

# Polyethylene terephthalate (PET)

**Peak capacity and production 2013 to 2016: 650,000 t/a**

- Mainly based on the Plant PET Technology Collaborative (PTC) initiative launched by The Coca Cola Company

**Significant decrease in actual production 2016 to 2020: 165,000 t/a**

- Operation rate for PET production is at 10 %, at least for 2 producers disclosing their production
- Annual decrease of 15 % of the production is estimated by the end of 2025
- Coca Cola, the main customer of bio-based PET, decided to not further use this bio-based alternative on large scale – all expansion plans were stopped (originally up to 7 Million t).
    - Decision of Coca Cola was due to low crude oil prices together with high production costs of MEG
    - The marketing effects of the GreenBottle were far less than expected (wrong product)
    - Major bio-based MEG producer is India glycols

# Worldwide PLA capacities

# 2011–2025

# (example)



**Table 36:** Worldwide production capacities of Polylactic acid (PLA) in 2011 - 2025 (in tonnes)

Lines highlighted in gray indicate that capacities are installed but no information on volume is known.

| Company | Location | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BBCA Biochemical & GALACTIC Lactic Acid Co., Ltd. | Bengbu (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30,000 | 50,000 |
| Chengdu Dikang Biomedical Co., Ltd. | Chengdu (China) | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 1,000 | 1,000 |
| Corbion | Georgia (United States) | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Corbion | Gorinchem (The Netherlands) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| DIC Corp. | Tokyo (Japan) | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 |
| Futerro | Escanaffles (Belgium) | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |
| Guangzhou Bio-plus Materials Technology Co., Ltd. | Guangzhou (China) | | | | | | | | | 10,000 | 10,000 | 10,000 |
| Henan Jindan Lactic Acid Technology Co., Ltd. | Dancheng (China) | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| Henan Piaoan Group Co., Ltd. | Chanyuan (China) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 10,000 | 10,000 |
| Hitachi Plant Technologies Ltd. | Kudamatsu (Japan) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Jilin COFCO Biomaterial Corporation | Changchun (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10,000 | 10,000 | 10,000 | 10,000 |
| Musashino Chemical Laboratory, Ltd. | Nanchang (China) | | | | | | | | | | | |
| Nantong Jiuding Biological Engineering Co., Ltd. | Rugao (China) | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| NatureWorks LLC | Blair (United States) | 140,000 | 140,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 165,000 |
| Shanghai Tong-Jie-Liang Biomaterials Co., Ltd. | Shanghai (China) | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 10,000 | 10,000 |
| Shenzhen Esun Industrial Co., Ltd. (formerly Shenzhen Bright China Industrial Co., Ltd.) | Shenzhen (China) | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| Shenzhen Guanghua Weiye Industry Co., Ltd. | Shenzhen (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,000 | 1,000 |
| Sichuan Dikang Sci & Tech Pharmaceutical Industry Co., Ltd. | Sichuan (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| Sinopec Group | Yushu (China) | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 10,000 | 10,000 |
| SK Chemicals Co., Ltd. | Suwon (South Korea) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| SPC Biotech Private Ltd. | Hyderabad (India) | 0 | 0 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Sulzer Chemtech AG | Winterthur (Switzerland) | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 |
| SUPLA Material Technology Co., Ltd. | Suqian (China) | 0 | 0 | 0 | 0 | 0 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| Teijin Ltd. | Iwakuni (Japan) | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| Teijin Ltd. | Matsuyama (Japan) | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 10,000 | 10,000 |
| Teijin Ltd. | Osaka (Japan) | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| thyssenkrupp Industrial Solutions AG (includes Uhde Inventa-Fischer AG and thyssenkrupp Uhde GmbH) | Berlin (Germany) | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| thyssenkrupp Industrial Solutions AG (includes Uhde Inventa-Fischer AG and thyssenkrupp Uhde GmbH) | Guben (Germany) | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| thyssenkrupp Industrial Solutions AG (includes Uhde Inventa-Fischer AG and thyssenkrupp Uhde GmbH) | unknown (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30,000 |
| Total Corbion | Grandpuits (France) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100,000 |
| Total Corbion | Rayong (Thailand) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 75,000 | 75,000 | 75,000 | 75,000 |
| Toyobo Co., Ltd. | Osaka (Japan) | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| Wuhan Sanjiang Space Good Biotech Co., Ltd. | Wuhan (China) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Yunan Fuji Bio-Material Technology Co., Ltd. | Kunming (China) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Zhejiang Hisun Biomaterials Co., Ltd. | Taizhou (China) | 5,000 | 5,000 | 5,000 | 5,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| Zhejiang Hisun Biomaterials Co., Ltd. | Unknown (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30,000 | 30,000 |
| Zhejiang Youcheng New Materials Co., Ltd. | Chongzuo (China) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,000 | 1,000 |
| Grand Total | | 172,827 | 172,827 | 183,837 | 183,837 | 193,837 | 203,837 | 203,837 | 288,837 | 298,837 | 395,137 | 560,137 |





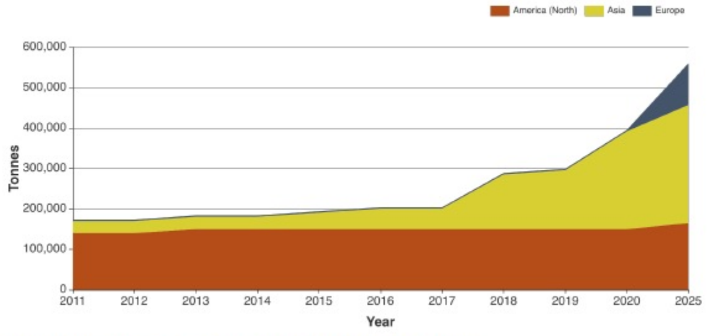



**Figure 43:** Worldwide production capacities of Polylactic acid (PLA) in 2011 - 2025 (in tonnes)

Company profile (example)

# 4.99 NatureWorks LLC

## Company Profile

NatureWorks LLC was established in 1989 as a 50/50 joint venture of Dow Chemical Co. and Cargill and is located in Minnetonka, USA. NatureWorks LLC is the leading company in polylactic acid (PLA) production. In 2004, Dow Chemical Co. left NatureWorks LLC. In 2007, Teijin Ltd. entered as a new partner but left in 2009.
In 2011, PTT Global Chemical invested $ 150 million in NatureWorks LLC in anticipation of NatureWorks LLC building a new production line in Thailand for start up in 2015.

In 2013, NatureWorks LLC announced that the company has located its first Asia Pacific regional headquarters in Bangkok and has expanded its team of senior commercial, managerial and technical personnel to enhance support of polylactic acid customers throughout the region and to expand business.The tactics of NatureWorks LLC were initially to produce PLA as a compostable plastic for disposable, one-time-use applications, such as packaging films and bottles, as well as homecare products. Their longer-term strategy is to move more and more into durable applications, like fibres & fabrics, automotive, and consumer electronics. NatureWorks LLC produces their PLA (Ingeo®) in Blair, Nebraska (USA) in a plant with a current name plate capacity of 150,000 t/a. In order to establish a market for their PLA grades, they offer PLA at price levels as low as € 2/kg or even lower for preferred customers. Prices as low as € 1.25/kg have been found in Europe. NatureWorks LLC makes quite an effort to develop the PLA market for fibres and already moves an estimated 40,000 t/a of PLA (2016) into this market. Most of it went into non-wovens, but newer grades also show progress in woven fabrics and in 3D printing. In 2017, NatureWorks LLC licensed Plaxica's Optipure® D-Lactic acid process technology to expand its Ingeo® product portfolio. NatureWorks LLC created a Vercet Technology for lactide and lactide-based performance materials.

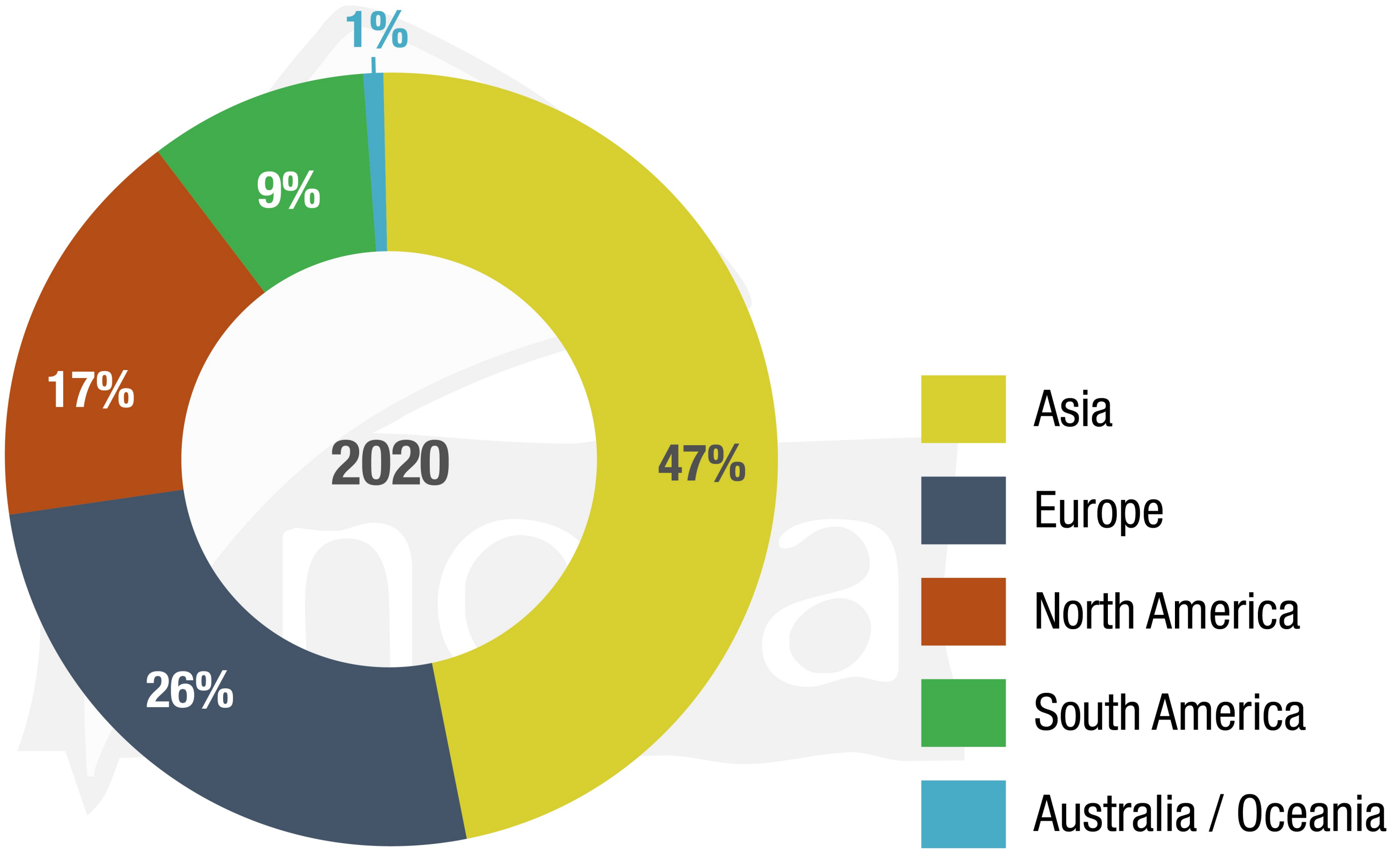
Products included in this report, worldwide production capacities in 2011 - 2025 (in tonnes)

Lines highlighted in gray indicate that capacities are installed but no information on volume is known.

| Product | Location | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lactic acid L-lactic acid (L-LA) | Blair (United States) | 0 | 0 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 198,000 |
| Lactide | Blair (United States) | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 220,000 |
| Polylactic acid (PLA) | Blair (United States) | 140,000 | 140,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | 165,000 |
| Grand Total | | 340,000 | 340,000 | 530,000 | 530,000 | 530,000 | 530,000 | 530,000 | 530,000 | 530,000 | 530,000 | 583,000 |

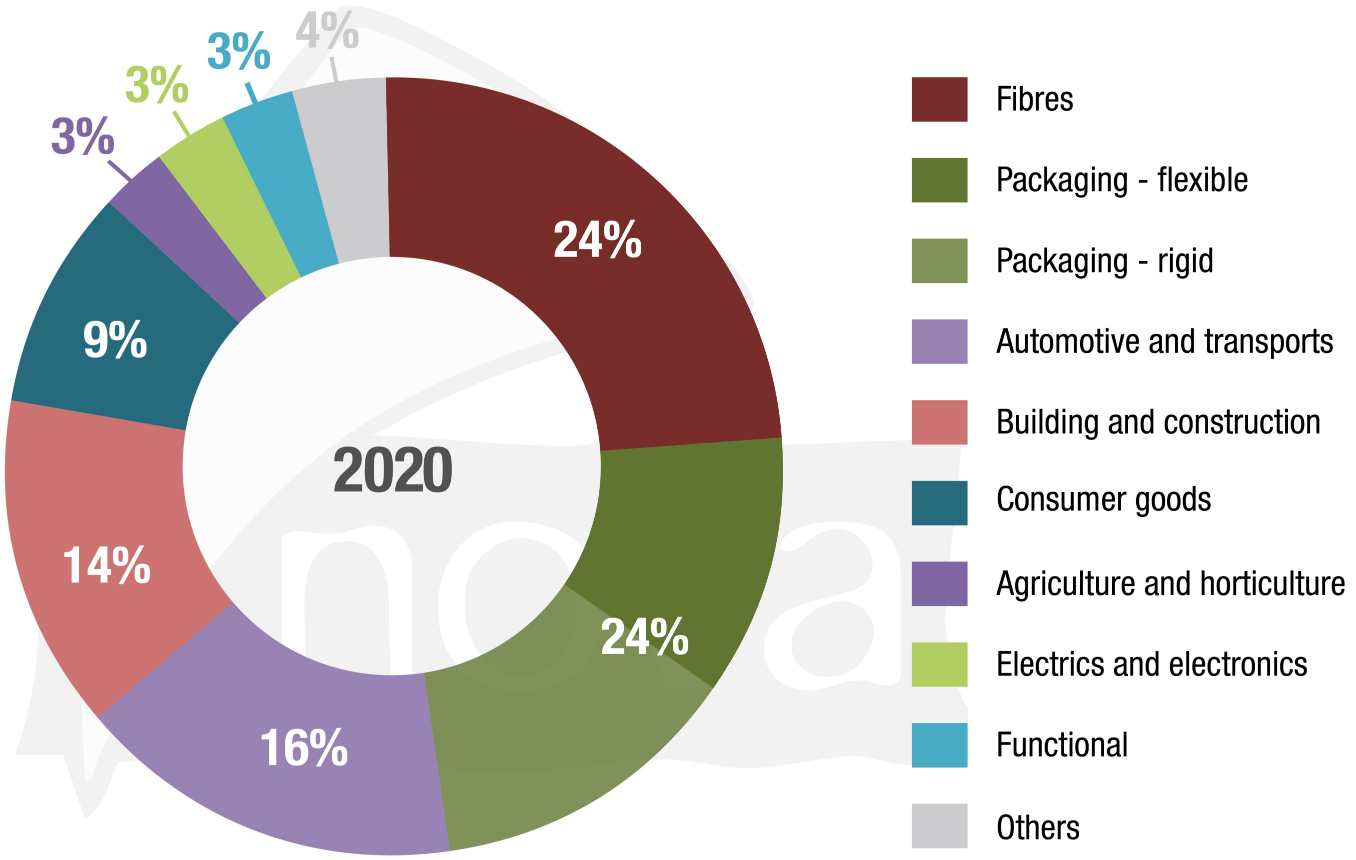
# Global production capacities of bio-based polymers per region 2020

without cellulose acetate, epoxy resins and polyurethanes




available at www.renewable-carbon.eu/graphics

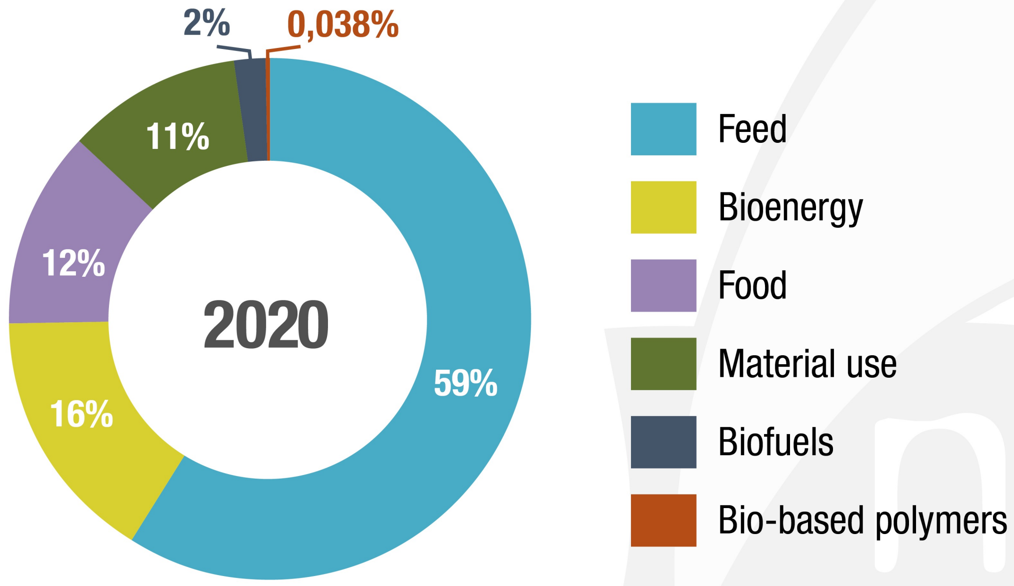
# Shares of the produced bio-based polymers in different market segments in 2020



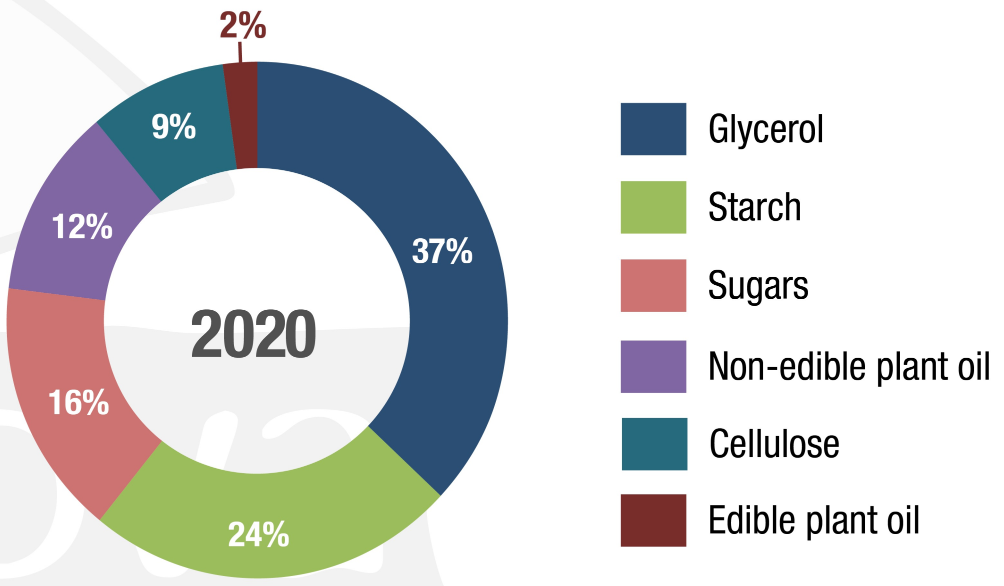

available at **www.renewable-carbon.eu/graphics**

# Biomass utilisation worldwide
# First and second generation, total and for bio-based polymers

**Worldwide biomass demand 2020, total: 12.54 billion tonnes**




**4.8 Mt biomass feedstock for 4.0 Mt bio-based polymers (with a 46 % share) in 2020 – worldwide**




The 0.038% share of biomass used to produce bio-based polymers translates into an area share of only 0.006%. This is due to various factors: high-yielding crops (like maize) are used for the production of bio-based polymers leading to a high area efficiency; the yields are not only used for polymer production but also for animal feed (the protein share) and thus only a part is allocated; and finally, because the biomass is a process by-product that uses no land (such as glycerol).

# Sustainability and Renewable Carbon



- The complete substitution of fossil carbon with **renewable carbon** from alternative sources: biomass, $CO_2$ and recycling is the way for **polymers, plastics and chemicals to become sustainable, climate-friendly and part of the circular economy**
- This necessary transition is already on the strategic agenda of several global brands, that are already expanding their feedstock portfolio to include, next to fossil-based, all three sources of renewable carbon
- This rethinking from the market point of view, especially in the use of biomass, will, and already did, increase the supply of bio-based as well as biodegradable polymers

# Remaining challenging market, low crude oil prices and little political support

**No political reward of the two major advantages of bio-based polymers:**

1) **Replacement of fossil carbon in the production process with renewable carbon from biomass**
   - This is indispensable for a sustainable, climate-friendly plastics industry and is not yet politically rewarded

2) **Biodegradability**
   - More than half of the produced bio-based polymers are biodegradable (depending on the environment)
   - Solution for plastics that cannot be collected and enter the environment
   - Can biodegrade without leaving behind microplastics
   - Only a few countries such as Italy, France and probably Spain will politically support this additional disposal path

# Important market drivers in 2019 and 2020

**The most important market drivers in 2018 and 2019:**

- Brands that want to offer their customers environmentally friendly solutions and critical consumers looking for alternatives to petrochemicals

**Future scenarios for a supportive, positive development of bio-based polymers:**

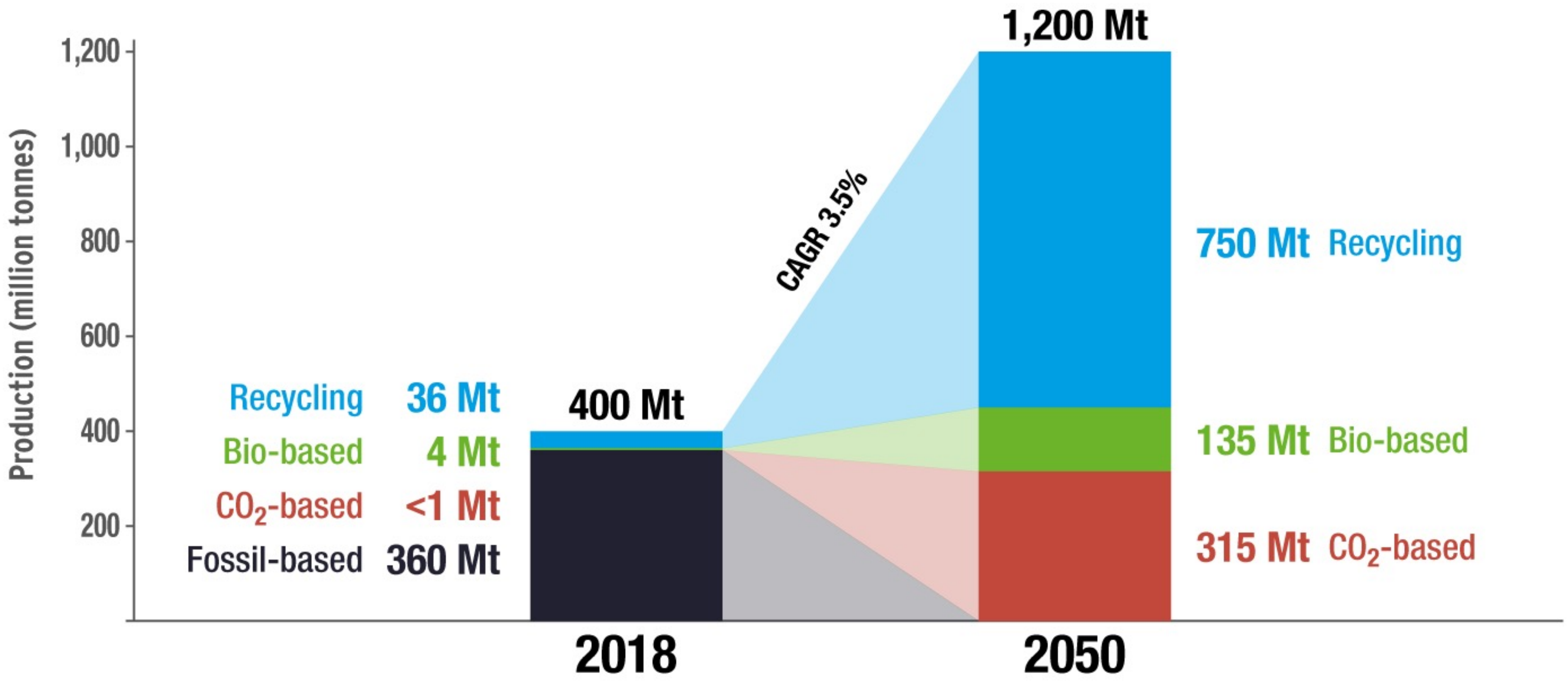
**Political support**

- If bio-based polymers were to be accepted as a solution and promoted in a similar way as biofuels, annual growth rates of 10 to 20 % could be expected

**Crude oil price**

- Same growth rates could be expected should the price of oil rise significantly
- Based on the already existing technical maturity of bio-based polymers, considerable market shares could be gained in these cases

# World Plastic Production and Carbon Feedstock in 2018 and Scenario for 2050 (in Million Tonnes)



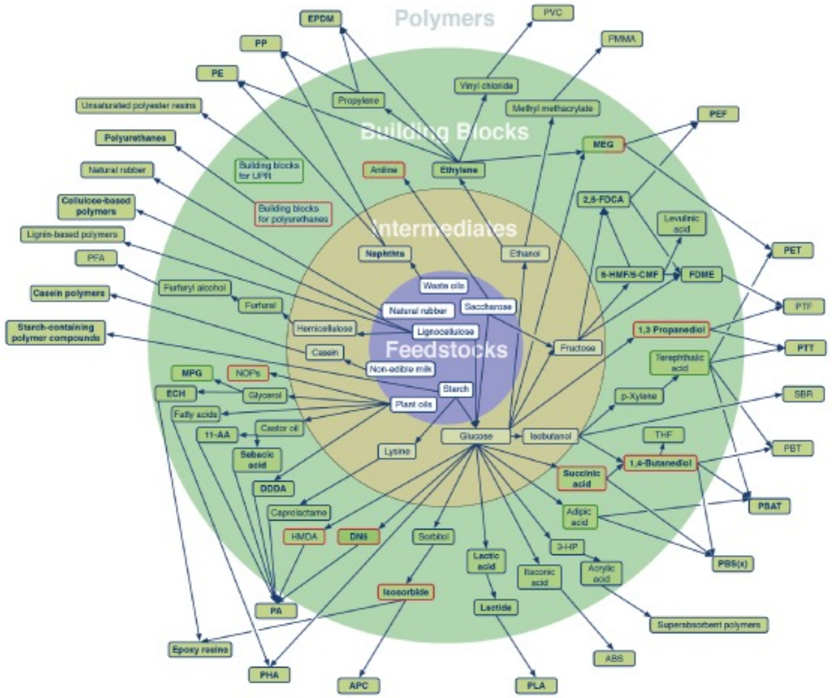

The virgin plastic production of 364 Million t in 2018 will increase to 450 Million t in 2050, completely based on renewable carbon. The total demand for plastics of 1,200 Million t in 2050 will be mainly covered by recycling.

DATA FOR 2020

nova Institute for Ecology and Innovation

RENEWABLE CARBON
renewable-carbon.eu

# Bio-based Building Blocks and Polymers – Global Capacities, Production and Trends 2020–2025




*Authors: Pia Skoczinski, Michael Carus, Doris de Guzman, Harald Käb, Raj Chinthapalli, Jan Ravenstijn, Wolfgang Baltus and Achim Raschka*

*January 2021*

This and other reports on renewable carbon are available at
**www.renewable-carbon.eu/publications**


- Published in January 2021
- Data for 2020
- 338 pages
- 17 bio-based building blocks and 17 polymers
- 174 company profiles
- € 3,000 – www.renewable-carbon.eu/publications

nova Institute for Ecology and Innovation

# Save the Date

RENEWABLE CARBON $CO_2$ renewable-carbon.eu

International Conference on
CELLULOSE FIBRES
2–3 February 2022
Hybrid Event

Conference on
$CO_2$-based Fuels
& Chemicals 2022
23 – 24 March • Hybrid Event

RENEWABLE
MATERIALS
CONFERENCE 2022
10-12 May
Hybrid Event

Contact: Mr. Dominik Vogt, +49 (0) 2233 48 14 49, dominik.vogt@nova-institut.de

All conferences at renewable-carbon.eu/events

# 9 Sessions, 18 Presentations
# Join Free Webinars on Markets and Strategies for Renewable Chemicals and Materials

**11 – 22 October 2021**

Hosted by nova-Institute and Wageningen University & Research

| | |
|---|---|
| **Monday, 11 October 2021** | |
| 14:00 - 15:30 CET | 01 The Renewable Carbon Vision |
| 15:30 - 17:00 CET | 02 Carbon Flows for Chemicals and Derived Materials and Carbon Management |
| **Thursday, 14 October 2021** | |
| 14:00 - 15:30 CET | 03 Technologies, Markets and Trends for "$CO_2$-based Products" |
| 15:30 - 17:00 CET | 04 Technologies, Markets and Policies on "Chemical Recycling" |
| **Tuesday, 19 October 2021** | |
| 13:00 - 14:30 CET | 05 Future of Refineries and Chemical Verbund Sites |
| 14:30 - 16:00 CET | 06 Circular & Plastic Policy |
| 16:00 - 17:30 CET | 07 Production Capacities, Markets and Trends for "Bio-based Building Blocks & Polymers" |
| **Friday, 22 October 2021** | |
| 14:00 - 15:30 CET | 08 Food vs. Non-Food Crops for Industry |
| 15:30 - 17:00 CET | 09 Useful Applications of Biodegradable Plastics |

**Where:**
Online via Zoom

Link to join Webinar: https://us02web.zoom.us/j/89492719676

# Thank you for your attention!

**Sustainability**
**M. Sc. Pauline Ruiz**
+49 (0) 2233 48 14-62
pauline.ruiz@nova-institut.de

Sustainability assessment / LCA
Chemicals, building blocks & polymers
Material Science

Stay in touch: **renewable-carbon.eu/newsletter**