Press release – long version

nova-Institute GmbH (www.nova-institute.eu)
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Bio-based polymers - Production capacity will triple from 3.5 million tonnes in 2011 to nearly 12 million tonnes in 2020

Bio-based drop-in PET and PE/PP polymers and the new polymers PLA and PHA show the fastest rates of market growth. The lion’s share of capital investment is expected to take place in Asia and South America.

Summary

Germany’s nova-Institute is publishing the most comprehensive market study of bio-based polymers ever made. The nova-Institute carried out this study in collaboration with renowned international experts from the field of bio-based polymers. It is the first time that a study has looked at every kind of bio-based polymer produced by 247 companies at 363 locations around the world and it examines in detail 114 companies in 135 locations. Considerably higher production capacity was found than in previous studies. The 3.5 million tonnes represent a share of 1.5% of an overall construction polymer production of 235 million tonnes in 2011. Current producers of bio-based polymers estimate that production capacity will reach nearly 12 million tonnes by 2020. With an expected total polymer production of about 400 million tonnes in 2020, the bio-based share should increase from 1.5% in 2011 to 3% in 2020, meaning that bio-based production capacity will grow faster than overall production.

The most dynamic development is foreseen for drop-in biopolymers, which are chemically identical to their petrochemical counterparts but at least partially derived from biomass. This group is spearheaded by partly bio-based PET (Bio-PET) whose production capacity will reach about 5 million tonnes by the year 2020, using bioethanol from sugar cane. The second in this group are bio-based polyolefins like PE and PP, also based on bioethanol. But “new in the market” bio-based polymers PLA and PHA are also expected to at least quadruple the capacity between 2011 and 2020. Most investment in new bio-based polymer capacities will take place in Asia and South America because of better access to feedstock and a favourable political framework. Europe’s share will decrease from 20% to 14% and North America’s share from 15% to 13%, whereas Asia’s will increase from 52% to 55% and South America’s from 13% to 18%. So world market shares are not expected to shift dramatically, which means that every region of the world will experience development in the field of bio-based polymer production.

Michael Carus, managing director of nova-Institute, reacted to the survey results thus: “For the very first time we have robust market data about worldwide production capacity of all bio-based polymers. This is considerably higher than in previous studies, which did not cover all polymers and producers. The forecast of a total capacity of 12 million tonnes by 2020 – a tripling of 2011 levels – suggests that bio-based polymers are definitely polymers for the future. It is also shown that the development of bio-based polymers is still very dynamic. Only five years ago, nobody would have expected bio-PET to grow to the biggest group among the bio-based polymers due to an initiative by one big brand-owner. This could happen again with any other bio-based polymer. PLA and PHA also have a remarkable growth ahead of them, even without the existence of such a ‘supply chain captain’.”
Study background

The bio-based polymers branch is a dynamic, versatile field, in which bio-based polymers have reached development stages that range from research level, via initial market adoption to long-term established performance plastics like cellulosics or nylon – all of them revealing significant market growth.

A number of factors affect the growth rate of the bio-based polymer branch. These factors include state policy, technology, feedstock cost, competition (biomass versus fossil fuels), crude oil prices, consumer acceptance, and, last but not least, access to clear and reliable market data.

There was in fact broad agreement - not only from the major industrial players but also from the user side - about the need for solid, transparent and worldwide market data about the bio-based polymer branch.

This need was a major stimulus for conducting this market survey. We have therefore tried to provide some clarity and transparency to the market by launching the most comprehensive international market study of bio-based polymers to date.

During a preparatory phase from August 2011 to the end of that year, interested stakeholders from the bio-based polymer branch were invited to become a partner of the study. The multi-client survey was funded by 26 renowned companies and institutions from 11 countries around the world. These companies had full access to intermediate results and sat on the Advisory Board, which met four times during the project (see the full list at http://www.bio-based.eu/market_study/).

Methodology

The field of bio-based polymers is broad and the available information very diverse and sometimes inconsistent. This can lead to confusion and misinterpreted results. It therefore seems crucial to explain the methodology that we used for this survey.

This study focuses exclusively on bio-based polymer producers, and the market data therefore does not cover the bio-based plastics branch. We must clearly differentiate between these two terms. A polymer is a chemical compound consisting of repeating structural units (monomers) synthesized through a polymerization or fermentation process, whereas a plastic material constitutes a blend of one or more polymers and additives.

Market data covers only the first polymer producers, excluding plastic and compound processing in an attempt to avoid double counting over the various steps in the value chain. Starch blends are the single exception among plastics to have been included in the market research. They are always used in complex blends of many components such as aliphatic polyesters (e.g. PCL, PLA, PBAT, PBS). In order to also avoid double counting here, it was attempted to leave out the capacities of bio-based polymers used in starch blends.

The focus of the study is on construction polymers, i.e. the polymers that will later constitute the structural mass of the finished plastic part. Functional polymers used in inks, coatings, adhesives or simply as a performance enhancer in other materials were only covered selectively and are not included in the totals given in this summary. Regenerated cellulose (e.g. cellophane and viscose), natural rubber and linoleum are beyond the scope of this study.

This market survey covers current market trends on bio-based polymers, i.e. derived from biomass (which may be biodegradable or not). However, we decided to include market data
on some polymers that are currently still fossil-based, namely polybutylene succinate (PBS) and polybutyleneadipat-terephthalate (PBAT). It may seem paradoxical, but the reasons for covering their production capacities are as follows. Their development is highly linked to the development of other bio-based polymers, as they are often used to enhance their properties in bio-based compounds. In the case of PBS, which is currently produced from fossil resources in relatively small quantities, the capacity development is spurred by the development of its bio-based precursors, as bio-based succinic acid can be produced at lower cost than its fossil-based alternative. They are both drop-in processable, i.e. every fossil-based PBS or PBAT producer can switch to bio-based PBS or PBAT if the bio-based diacids and diols become available, with no need to change equipment. From announcements and seeing the capacity development in their bio-based precursor chemicals, the polymers of the companies covered here are expected to be increasingly bio-based, reaching shares of 50% (PBAT) and 80% (PBS) by 2020.

This study considers only announced capacities. The research work is based on the analysis and discussion of existing publications, press releases and market studies, questionnaires, face-to-face expert interviews (many at CEO level), and expert workshops and conferences held during the study period. On the other hand, the database gathers a broader list of companies, e.g. start-ups that have no announced volumes as yet but may become leading companies in the future. The database will be continuously updated and act as a perfect database for future market surveys.

The total estimate of polymer production capacity in 2020 is mainly based on the forecasts of companies already producing bio-based polymers (or precursors) today. That could lead to an underestimation of future capacities, because the method does not take account of new players.

Table 1 gives an overview on the covered bio-based polymers and the producer companies with their locations. The database contains a total of 247 companies in 363 locations. More detailed information is provided for 114 companies in 135 locations.

The average biomass content of the polymers (Table 1) is used to generate Figure 3 from Figure 2.
## Table 1: Bio-based polymers, short names, average biomass content, producer companies and locations

<table>
<thead>
<tr>
<th>Bio-based polymers</th>
<th>Average biomass content of polymer</th>
<th>Producers companies until 2020</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose Acetate CA</td>
<td>50%</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Polyamide PA</td>
<td>rising to 60%*</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Polybutylene Adipate Terephthalae PBAT</td>
<td>rising to 50%*</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Polybutylene Succinate PBS</td>
<td>rising to 80%*</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Polyethylene PE</td>
<td>100%</td>
<td>3**</td>
<td>2</td>
</tr>
<tr>
<td>Polyethylene Terephthalae PET</td>
<td>30% to 35%***</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Polyhydroxy Alkanoates PHAs</td>
<td>100%</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Polylactic Acid PLA</td>
<td>100%</td>
<td>27</td>
<td>32</td>
</tr>
<tr>
<td>Polypolypropylene PP</td>
<td>100%</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Polyvinyl Chloride PVC</td>
<td>43%</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Polyurethane PUR</td>
<td>30%</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Starch Blends ****</td>
<td>40%</td>
<td>19</td>
<td>21</td>
</tr>
</tbody>
</table>

**Total companies covered with detailed information in this report** | 114 | 135 |

**Total companies and locations recorded in the market study** | 247 | 363 |

* Currently still mostly fossil-based with existing drop-in solutions and a steady upward trend of the average bio-based share up to given percentage in 2020
** Including Joint Venture of two companies sharing one location, counting as two
*** Upcoming capacities of bio-pTA (purified Terephthalic Acid) are calculated to increase the average bio-based share, not the total bio-PET capacity
**** Starch in plastic compound
Main results

Building blocks and monomers as a precursor of polymers

Figure 1 shows the most important pathways from biomass to building blocks to polymers. The thickness of the arrows is related to the current market relevance of the corresponding building blocks, while the yellow coloured areas illustrate the direct conversion of different polymers (namely natural rubber, starch-based polymers, lignin-based polymers and cellulose-based polymers) from biomass. Finally, green-coloured pathways correspond to the routes derived from glucose, whereas the purple and the orange ones coincide with the glycerol and fatty acid pathways respectively. Only existing routes currently engaged in industrial production have been taken into consideration. There are many more pathways under research or at pilot stage. However, one can clearly see that bio-based chemical producers currently have the potential to build extensive alternative supply chains for a variety of chemicals and polymers (e.g. PU, PA).

There is a strong growth in the market for bio-based precursors for drop-in solutions, which are also partially covered by the report and database. Often there are not yet any announced capacities at the polymer producer stage, so the study could not reflect the volumes of polymers derived from these precursors.

There is also a strong upward potential for bio-based PA precursors for example, as well as plans to make commodity PA like nylon 6.6 and nylon 6 (partly) bio-based. For different building blocks like adipic acid (2,800 kt market in total), HMDA, caprolactam, etc. the bio-based market share is purely a matter of price compared to petrochemical routes, which is already lower in some cases.

The ongoing increase in bio-based MEG and pTA capacity has a considerable impact on the production capacities of partly bio-based PET. Our forecast for the total Bio-PET production capacity is based on the forecast of bio-based MEG production capacity in particular – supported by announcements of future market demand.
Bio-based polymers

The report shows that the production capacity of bio-based polymers will triple from 3.5 million tonnes in 2011 to nearly 12 million tonnes by 2020. Bio-based drop-in PET and PE/PP polymers and the new polymers PLA and PHA show the highest growth rates on the market. Most capital investment is expected to take place in Asia and South America.

It is the first time that a study has looked at every kind of bio-based polymers produced by 247 companies at 363 locations around the world, and it examines 114 companies in 135 locations in detail (see Table 1). Considerably higher production capacity was found than in previous studies. The 3.5 million tonnes represent a share of 1.5% of an overall construction polymer production of 235 million tonnes in 2011. Current producers of bio-based polymers estimate that production capacity will reach nearly 12 million tonnes by 2020. With an expected total polymer production of about 400 million tonnes in 2020, the bio-based share will increase from 1.5% in 2011 to 3% in 2020, meaning that bio-based production capacity will grow faster than overall production.

Figures 2 and 3 show the main results of the survey. The most dynamic development is foreseen for bio-based PET (Bio-PET) with production capacity of about 5 million tonnes by the year 2020, based on bioethanol from sugar cane. The second are also drop-in biopolymers, which are chemically identical to their petrochemical counterparts but derived from biomass. Bio-based polyolefins like PE and PP, are polymerized from components, based on bioethanol. But also the “new” PLA and PHA bio-based polymers will more than quadruple their capacity between 2011 and 2020. There follow some details about Bio-PET and PLA. Many more details – including on other polymers – can be found only in the full report.
Bio-based PET

The Coca-Cola Company, Ford Motor Company, H.J. Heinz Company, NIKE Inc. and Procter & Gamble announced in 2012 the formation of the Plant PET Technology Collaborative (PTC), a strategic working group focused on accelerating the development and use of 100% plant-based PET materials and fibre in their products. In just a few short years, The Coca-Cola Company has expanded from producing PlantBottle™ plastic in a single location to now having facilities in most of their major markets, with further expansion to come.

When such brand corporations join forces and build alliances, their impact on the supply chain becomes inevitably visible. Mono-ethylene glycol (MEG), a key component of PET resins, is already going to be produced in high volumes as bio-based diol in India (Indian Glycols LTD., 175,000 t/a) and Taiwan (Greencol Taiwan, 100,000 t/a). The Indian company JBF Industries plans for additional MEG capacities of 500,000 t/a in Brazil to come on-stream after 2015. Also developments in the production of bio-based purified terephthalic acid, the other monomer of bio-PET, have been announced.

As these precursors can be used to produce partly bio-based PET in any existing PET facility at relatively short notice, only very little of the bio-MEG capacity to come already matches announcements about the production of bio-PET. Companies already dedicating part of their PET capacities to the production of bio-PET are for example Teijin and Indorama Venture, both located in Asia, with 100,000 t/a and 300,000 t/a respectively.

In the year 2011 about 620,000 tonnes bio-based PET were produced from bio-MEG, expected to grow to a production capacity of nearly 5 million tonnes in 2020.

PLA – polylactic acid

At 30 sites worldwide 25 companies have developed a production capacity of (presently) more than 180,000 tonnes per annum (t/a) of polylactic acid (PLA), which is one of the leading bio-based polymers. The largest producer, NatureWorks, had a capacity of 140,000 t/a in 2011. The other producers have current capacity of between 1,500 and 10,000 t/a.

According to their own forecasts, existing PLA producers are planning to considerably expand their capacity to reach around 800,000 t/a by 2020 (see Figure 2). There should be at least seven sites with a capacity of over 50,000 t/a by that time. A survey of lactic acid producers (the precursor of PLA) revealed that production capacity could even rise to roughly 950,000 t/a to meet concrete requests from.
In contrast to Figure 2, showing the evolution of production capacities of bio-based polymers, Figure 3 shows only the biomass content of the bio-based polymers. Because this share is much higher for the “new to the market” polymers like PLA and PHA compared to PET and PVC drop-ins, the polymer shares are different, as is total capacity.
Investment by region

Most of the investment in new bio-based polymer capacities will take place in Asia and South America because of better access to feedstock and favourable political frameworks.

Asia has become a key region for bio-based polymers and their precursors. Some examples are current developments in Thailand (Purac, PTT), India (India Glycol Ltd.), Taiwan (Greencol Taiwan), China (Henan Jindan, Shenzhen Ecomann, Tianan Biologic Materials, Tianjin Green Biomaterials) or Japan (Kaneka, Teijin Limited, Toyota), which include future or existing production of lactic acid, lactide, succinic acid, 1,4-BDO, MEG, PET and PHA.

The expanding global utilization of bio-ethanol for chemical building blocks has led to the establishment of large-scale production facilities for bio-based MEG in India and Taiwan and for bio-ethylene, precursor for e.g. PE, MEG but also EPDM, in Brazil. Furthermore, the bio-based drop-in market is developing fast in Asia, where many converters are SMEs and cannot afford important alterations to their existing processing equipment.

Europe’s share will decrease from 20% to 14% and North America’s share from 15% to 13%, whereas Asia’s will increase from 52% to 55% and South America’s from 13% to 18%.
Figure 4: Evolution of the shares of bio-based production capacities in different regions

Share of bio-based polymers in the total polymer market

The final figure 5 gives an overview of all kinds of polymers including rubber products, man-made fibres and functional polymers – and not simply construction polymers as usual. This figure includes bio-based shares at different levels.

Figure 5: Polymers worldwide, bio-based shares (mostly 2011)
The share for construction polymers, which are the focus of the study, is 1.5%, but for polymers overall the bio-based share is even higher (8.2%) because of the higher bio-based shares in rubber (natural rubber) and man-made fibres (cellulosic fibres).

**Content of the full report**

This over 360-page report presents the findings of nova-Institute’s year-long market study, which is made up of three parts: “market data”, “trend reports” and “company profiles”

The “market data” section presents market data about total production and capacities and the main application fields for selected bio-based polymers worldwide (status quo in 2011, trends and investments towards 2020). Due to the lack of 100% reliable market data about some polymers, which is mainly due to the complexity of their manufacturing value chain structure (namely thermosets, cellulose acetate) or their pre-commercial stage (CO₂-based polymers), this section contains three independent articles by experts in the field who present and discuss their views on current and potential market development. However, this part not only covers bio-based polymers, but also investigates the current bio-based building block platforms.

The “trend reports” section contains a total of six independent articles by leading experts in the field of bio-based polymers and plastics. Dirk Carrez (Clever Consult) and Michael Carus (nova-Institute) focus on policies that impact on the bio-based economy. Jan Ravenstijn analyses the main market, technology and environmental trends for bio-based polymers and their precursors worldwide. Wolfgang Baltus (NIA) reviews Asian markets for bio-based resins. Roland Essel (nova-Institute) provides an environmental evaluation of bio-based polymers, and Janpeter Beckmann (nova-Institute) presents the findings of a survey concerning Green Premium within the value chain leading from chemicals to bio-based plastics. Finally, Harald Kaeb (narocon) reports detailed information about brand strategies and customer views within the bio-based polymers and plastics industry. These trend reports cover in detail every recent issue in the worldwide bio-based polymer market.

The final “company profiles” section includes 114 company profiles with specific data including locations, bio-based polymers, feedstocks, production capacities and applications. A company index by polymers, and list of acronyms follow.

“Bio-based Polymers Producer Database” and updates to the report

To conduct this study nova-Institute developed the “Bio-based Polymers Producer Database”, which includes a company profile of every company involved in the production of bio-based polymers and their precursors. This encompasses (state of affairs in 2011 and forecasts for 2020) basic information on the company (joint ventures, partnerships, technology and bio-based products) and its various manufacturing facilities. For each bio-based product, the database provides information about production and capacities, feedstocks, main application fields, market prices and bio-based share.

Access to the database will be available end of April 2013. The database will be constantly updated by the experts who have contributed to this report. Buyers of the report will have free access to the database for one year.

nova-Institute will generate an annual update of the report based on the existing report and the continuously updated database.
Authors of the study

**Wolfgang Baltus** (PhD) (Thailand) worked for BASF for 15 years and was responsible for the business development of environmental friendly coatings in Asia. Since 2008 Baltus has been working for the National Innovation Agency (NIA) in Bangkok. He is regarded as one of the leading experts on bio-based polymer markets and policy in Asia.

**Dirk Carrez** (PhD) (Belgium) is one of the leading policy consultants on a Bio-based Economy in Brussels. He was director of EuropaBio, the European Association for Bioindustries, until 2011. He is now Managing Director of Clever Consult, Brussels. In 2013 he was hired to be the coordinator of the new industrial association BIC (Bio-based Industries Consortium), which will organise the PPP (BRIDGE – Bio-based and Renewable Industries for Development and Growth in Europe) between the EU Commission and more than 40 bio-based economy companies.

**Michael Carus** (Dipl.-Phys.) (Germany) is a physicist and founder and managing director of nova-Institute. He has worked in the Bio-based Economy field for over 15 years. This includes biomass feedstock, bio-based chemistry, plastics, fibres and composites. His work focuses on market analysis, techno-economic and ecological evaluation and creating the political and economic framework for bio-based processes and applications. Carus is main author of the “Policy paper on Bio-based Economy in the EU: Level Playing Field for Bio-based Chemistry and Materials”, and is considered to be one of the leading experts for the industrial material use of biomass.

Seven experts from the nova-Institute team contributed to the study, and Adriana Sanz Mirabal managed the project for nova-Institute.

**Harald Kaeb** (PhD) (Germany) is a chemist and has an unblemished 20-year "bio-based chemistry and plastics" track record. From 1999 to 2009 he chaired the board and built up “European Bioplastics”, the association that represents the bioplastics industry in Europe. Since 1998 he has worked as an independent consultant helping green pioneers and international brands to develop and implement smart business, media and policy strategies for bio-based plastics.

**Jan Ravenstijn** (MSc) (The Netherlands) has more than 35 years experience in the chemical industry with Dow Chemical and DSM, including 15 years in executive global R&D positions in engineering plastics, thermosets and elastomers. He is currently a visiting professor and consultant to the CEOs of biopolymer companies and has published several papers and articles on the market development of bio-based polymers. Ravenstijn is regarded as one of the world’s leading experts in his field.

**Stefan Zepnik** (PhD) (Germany) studied Business Engineering at the Martin Luther University Halle-Wittenberg and gained his PhD at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. He became group manager for “Material Development” at the “Bio-based Plastics” department in 2013.
Order the full report

The full 360-page report contains three main parts - “market data”, six “trend reports” and 114 “company profiles” - and can be ordered for 6,500 € plus VAT at:

www.bio-based.eu/market_study

This also includes one-year access to the “Bio-based Polymers Producer Database”, which will be continuously updated.

Figures

The figures included in this release can be downloaded in high resolution at http://www.bio-based.eu/market_study/pressrelease

The zip-file includes:

- 13-03-06_Biomass_Polymers: “From biomass to polymers”
- 13-03-06_Figure_total: “Bio-based polymers: evolution of production capacities from 2011 to 2020”
- 13-03-06_Figure_bb-share: “Biomass content applied in bio-based polymers: evolution of production capacities from 2011 to 2020”
- 13-03-06_Region_share: „Evolution of the shares of bio-based production capacities in different regions”
- 13-03-06_Polymers_worldwide: "Polymers worldwide, bio-based shares (mostly 2011)"

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