

# **Market Developments of and Opportunities for biobased products and chemicals**

**Final Report**

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# 1 Introduction and executive summary

This study was written for NL Agency in order to analyse important global growth markets for bio-based materials and to identify the current position of the Netherlands as well as opportunities for new developments in these markets. It is structured into four parts: First, market data will be provided for bio-based polymers, for Natural-Fibre-Reinforced Composites (NFC) and for Wood-Plastic Composites, which covers most of the important bio-based growth markets identified by nova-Institute (see yellow fields in Figure 1). Within the scope of the project, it was not possible to cover lubricants and surfactants, too, which are also increasingly bio-based and show significant growth. Biofuels and bioenergy are not covered by this report. Due to limited resources, the data shown in this report is drawn from several other studies conducted by nova-Institute. For the first part, the bio-based polymers, results are presented from our market study “Bio-based Polymers in the World – Production, Capacities and Applications: Status Quo and Trends towards 2020” which was published in 2012 and which is continuously updated. The market report itself is several hundred pages long and consists additionally of a database of all producers of bio-based polymers worldwide, which is also regularly kept up-to-date. For more information, please visit [http://www.bio-based.eu/market\\_study/](http://www.bio-based.eu/market_study/). For this study for NL Agency, the most significant information has been extracted from the study and is presented in Chapter 2.

The report comes to the conclusion, that an expansion of bio-based polymer production capacity from today 3.5 million tonnes to 12 million tonnes in 2020 will take place according to plans of producers. That would mean an increase in shares of the total construction polymer production world-wide from 1.5 % to 3 %. Especially dynamic developments are expected for drop-in solutions.

For NFC and WPC, another big market study conducted by nova-Institute is the basis of information. The study “Wood-Plastic Composites (WPC) and Natural-Fibre Composites (NFC): European and Global Markets 2012 and Future Trends” will be published in February 2014. For the purpose of the study for NL Agency, again the most significant results were extracted and are presented here in the final report. For NFC, we are focusing completely on the automotive sector, because it is the only market of volume, which has any relevance for European manufacturers. There are a few other niche markets, but they are not treated here. For WPC, decking is still the most important application, but other applications are slowly gaining market shares. The most dynamic production development of WPC is seen in China, which is expected to overtake other production regions until 2015.

It should be mentioned that it is generally quite challenging to obtain market information on bio-based economic activities. The three market sections were chosen because of their relevance to the European market and also because of practical considerations such as information availability.

The following chapter 3 looks at price developments of different feedstocks and compares price levels of conventional and bio-based plastics. Again, the availability of information for bio-based materials is very limited, but the findings show that bio-based plastics are placed on the market at higher prices than most conventional plastics. A section on “Green Premium” discusses the reasons for this and finds that a combination of perceived “emotional performance” and “strategic performance” provides several reasons for bio-based plastics to be able to be sold at prices above conventional market levels.

After these global considerations, the position of the Netherlands on these markets will be assessed by looking at existing bio-based economic activities and analysing strengths and weaknesses of the location. Finally, the political framework supporting bio-based industries will be analysed and recommendations will be derived.

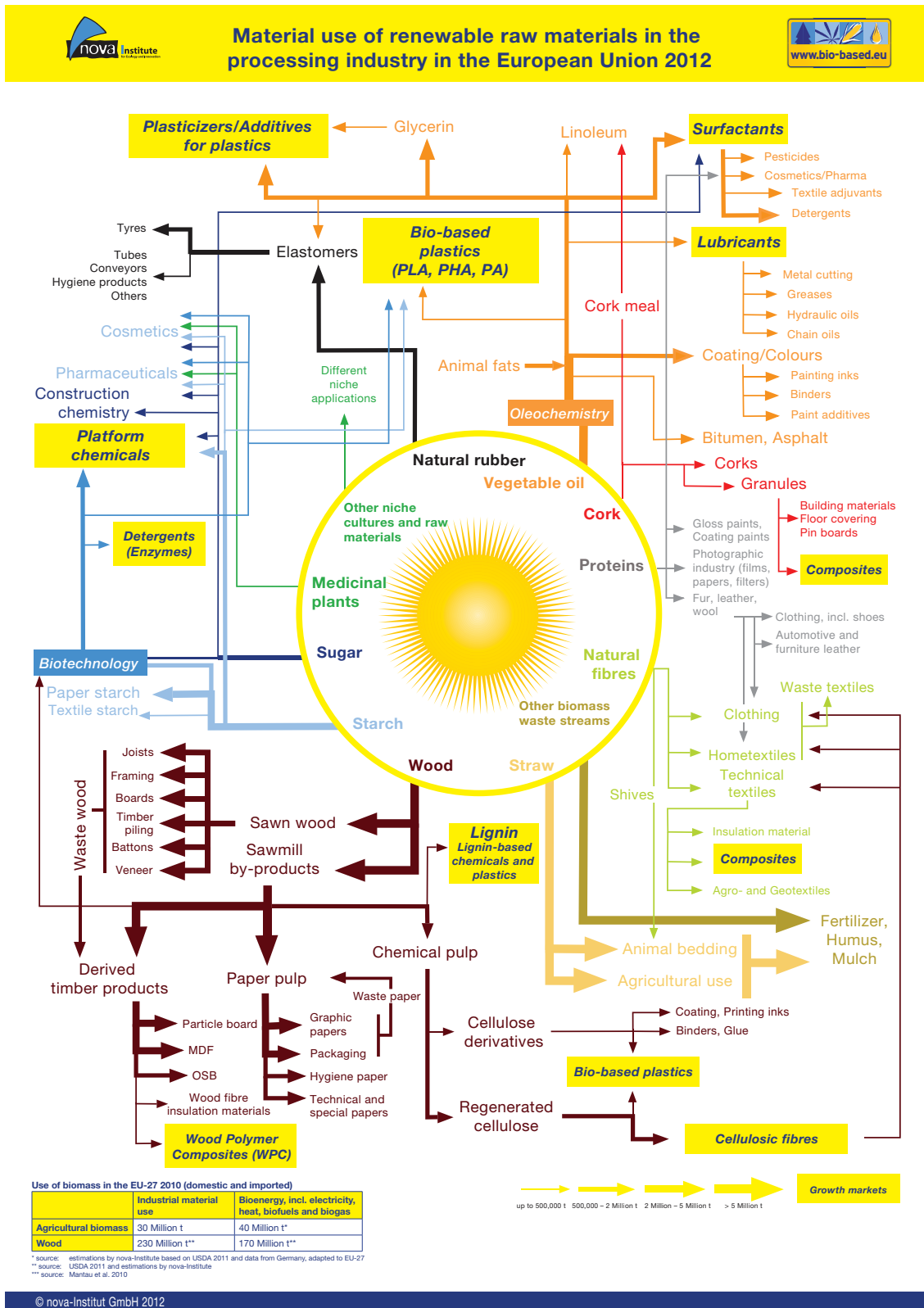


Figure 1: Bio-based chemicals and materials (nova-Institute 2012)

## **2 Evaluation of Markets and Trends in Bio-based Economy**

### **2.1 Bio-based polymers**

#### **2.1.1 Introduction**

The market study “Bio-based Polymers in the World – Production, Capacities and Applications: Status Quo and Trends towards 2020”, which is the basis for this Chapter, was executed by nova-Institute and is the most comprehensive study in this field ever made. It was carried out 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 overall sum of 3.5 million tonnes that were found for 2011 represent a share of 1.5% of an overall construction polymer production of 235 million tonnes. 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.

#### **2.1.2 Study background and methodology**

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 cellulose 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.

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 was 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 Polybutylene adipate 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 report of the Market Study contains a total of 247 companies in 363 locations. More detailed information is provided for 114 companies in 135 locations. The database is continuously updated.



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**

Bio-based polymers		Average biomass content of polymer	Producing companies until 2020	Locations
Cellulose Acetate	CA	50%	9	15
Polyamide	PA	rising to 60%*	14	17
Polybutylene Adipate Terephthalate	PBAT	rising to 50%*	3	3
Polybutylene Succinate	PBS	rising to 80%*	11	12
Polyethylene	PE	100%	3**	2
Polyethylene Terephthalate	PET	30% to 35%***	4	4
Polyhydroxy Alkanoates	PHAs	100%	14	16
Polylactic Acid	PLA	100%	27	32
Polypropylene	PP	100%	1	1
Polyvinyl Chloride	PVC	43%	2	2
Polyurethane	PUR	30%	10	10
Starch Blends ****		40%	19	21
<b>Total companies covered with detailed information in this report</b>			<b>114</b>	<b>135</b>
Additional companies included in the "Bio-based Polymer Producer Database"			133	228
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

### 2.1.3 Main results

#### Building blocks and monomers as a precursor of polymers

Figure 2 shows the most important pathways from biomass to building blocks to polymers.

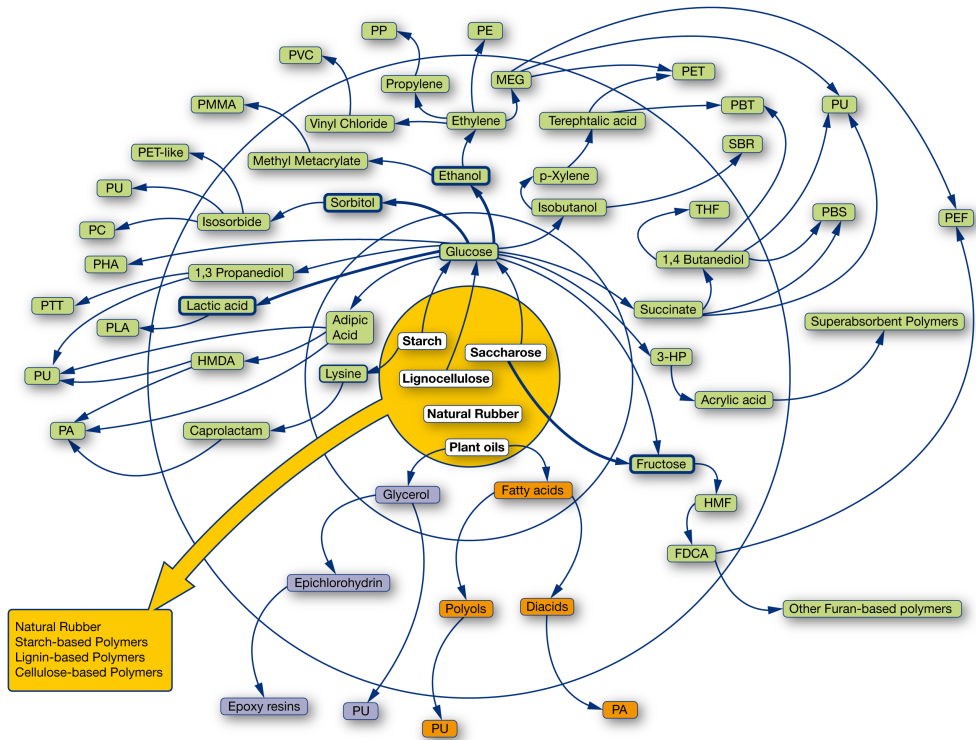
The thickness of the arrows is related to the current market relevance of the corresponding building blocks, while the yellow coloured areas illustrate the direct conversion of different polymers (namely natural rubber, starch-based polymers, lignin-based polymers and cellulose-based polymers) from biomass. 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.

# FROM BIOMASS TO POLYMERS



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Figure 2: From biomass to polymers

We have analysed the production capacity of the most important bio-based building blocks that are precursors of polymers until 2020 on a global scale (Table 2, Figure 3).

**Table 2: Worldwide production capacities of bio-based building blocks 2011-2020**

Bio-based building blocks	Producing companies worldwide until 2013*	Production capacities worldwide 2011* (t/a)	Production capacities worldwide 2013* (t/a)	Production capacities worldwide 2020* (t/a)
1,3 Propanediol	2	confidential	78,000	120,000
1,4-Butanediol	0	0	0	216,010
2,3-Butanediol	1	80,000	80,000	80,000
Adipic acid	3	0	n.a.	n.a.
Azelaic acid	1	0	0	n.a.
Paraxylene	3	33	1,473	201,473
Butanol	1	64,500	64,500	100,000
Epichlorohydrin	6	44,000	395,000	495,000
Ethylene	4	300,000	478,000	840,000
Furanic building blocks	1	30,000	30,000	30,000
Isobutanol	1	0	169,500	169,500
Isosorbide	1	3,000	3,000	3,000
Lactic acid (L-D-L+D)	6	209,000	284,000	375,000
Monoethylene glycol	4	300,000	400,000	1,605,000
Natural oil polyols	4	46,200	46,200	47,200
Polyether polyol	4	55,000	85,000	85,000
Propylene	0	0	0	50,000
Propylene glycol	2	200,000	395,000	395,000
Sebacic acid	1	22,000	22,000	22,000
Succinic acid	5	3,200	25,000	250,000
Terephthalic acid	1	0	110	110
Other building blocks	4	85,000	85,000	85,000
<b>Total</b>	<b>55</b>	<b>ca. 1.222.000</b>	<b>2,641,783</b>	<b>5,169,293</b>

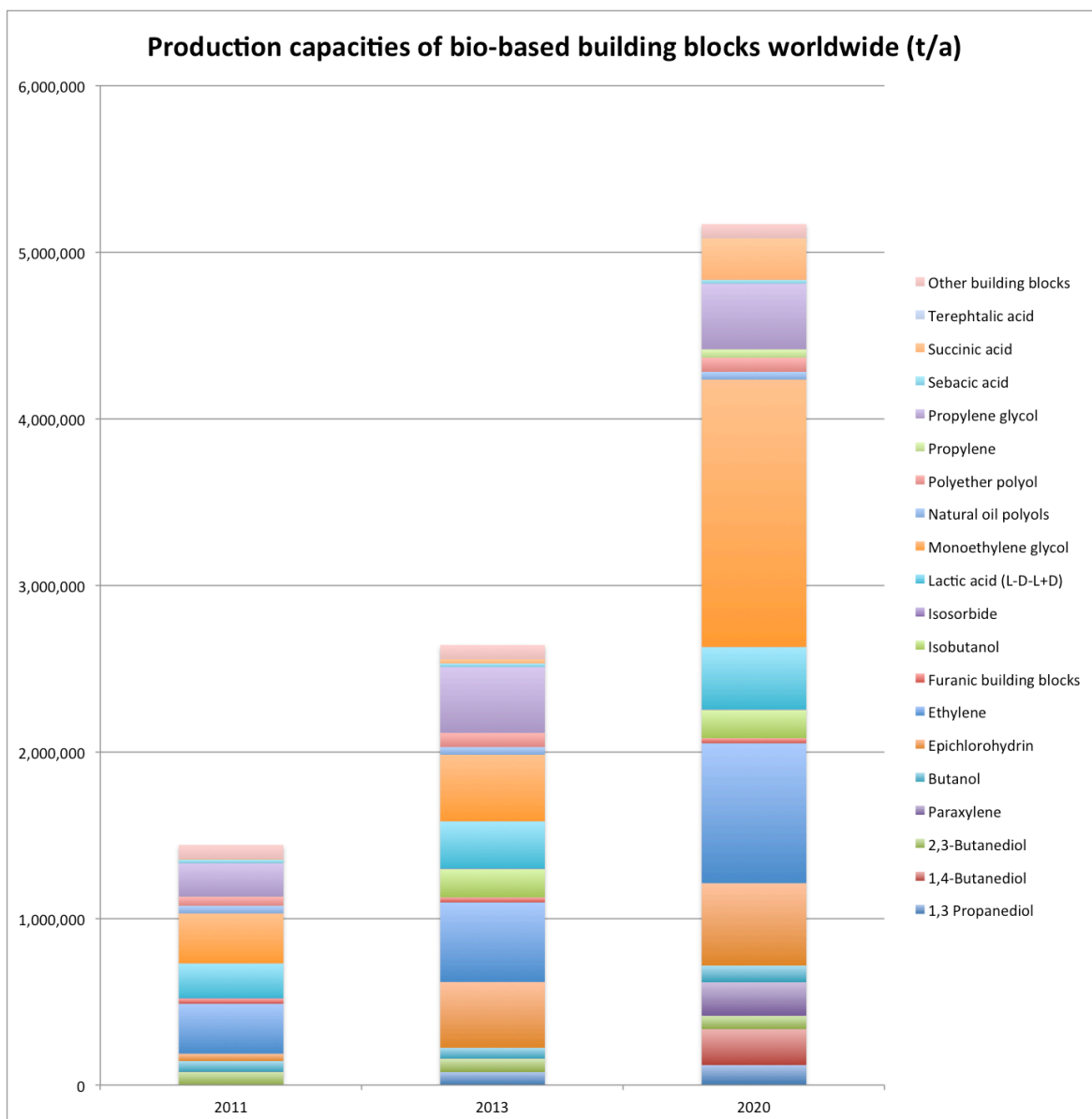


Figure 3: Worldwide production capacities of bio-based building blocks 2011-2020.

As can be seen from these illustrations, strong growth is expected for succinic acid, 1,4-Butanediol, Ethylene and Monoethylene glycol, Paraxylene and Terephthalic acid as well as Epichlorohydrin. Paraxylene and its product Terephthalic acid as well as Monoethylene glycol (with its precursor Ethylene) are used together for the production of bio-based PET. Coca Cola’s strong interest in the “Plant bottle” is one of the main drivers for the growth of these building blocks. Especially from Ethylene, many more products are foreseen for future manufacturing, such as bio-based PE, PP and PVC. Succinic acid is a precursor for several products, mainly polyesters such as Polybutylensuccinate (PBS) and for 1,4-Butanediol (BDO) to produce e.g. Polytetrahydrofurane (PolyTHF by BASF) and Polybutylenterephthalate (PBT by Lanxess). The Epichlorohydrin is a drop-in for the production of epoxy resins for several applications, e.g. the production of rotor blades for wind turbines.

### 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.

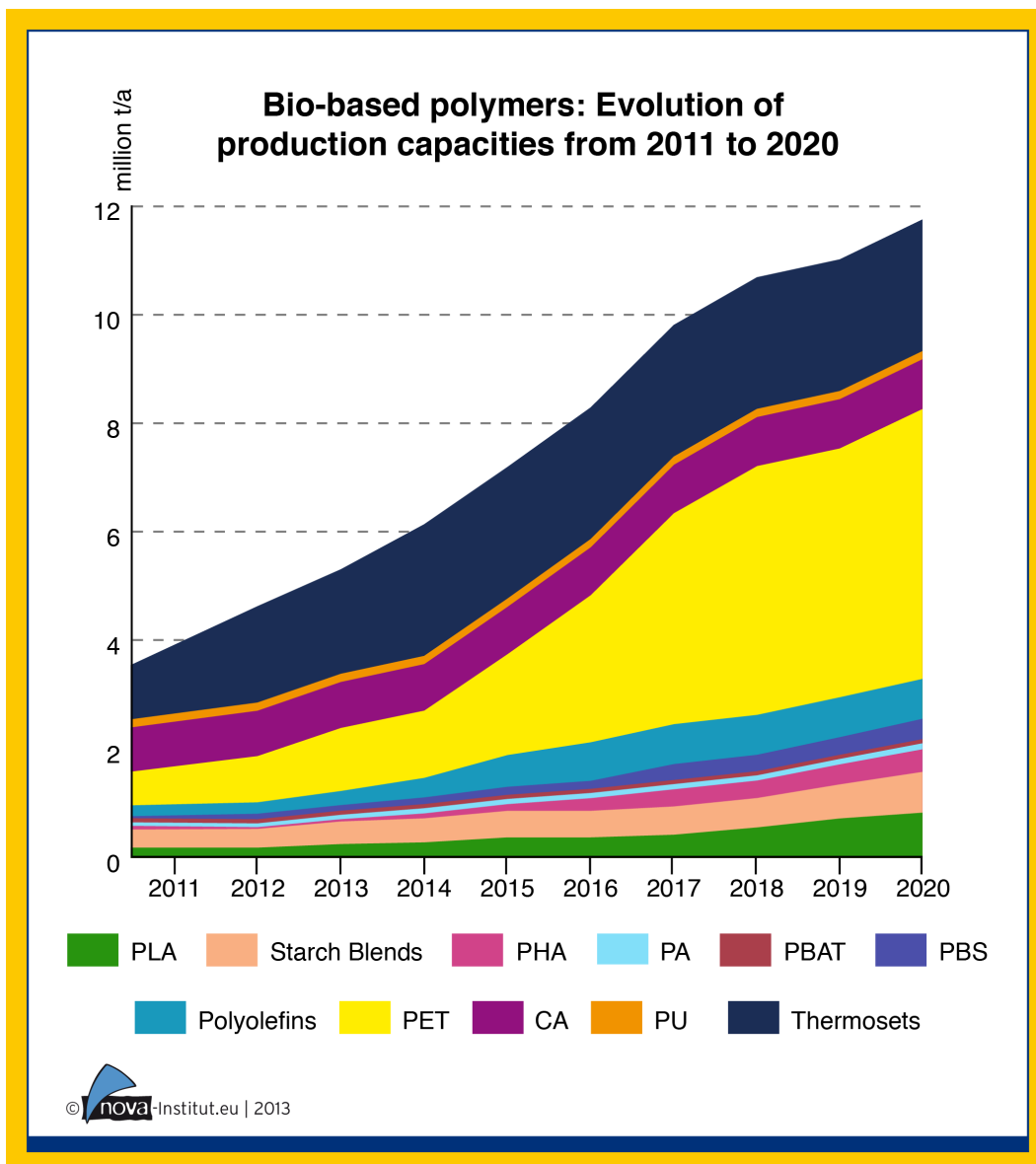
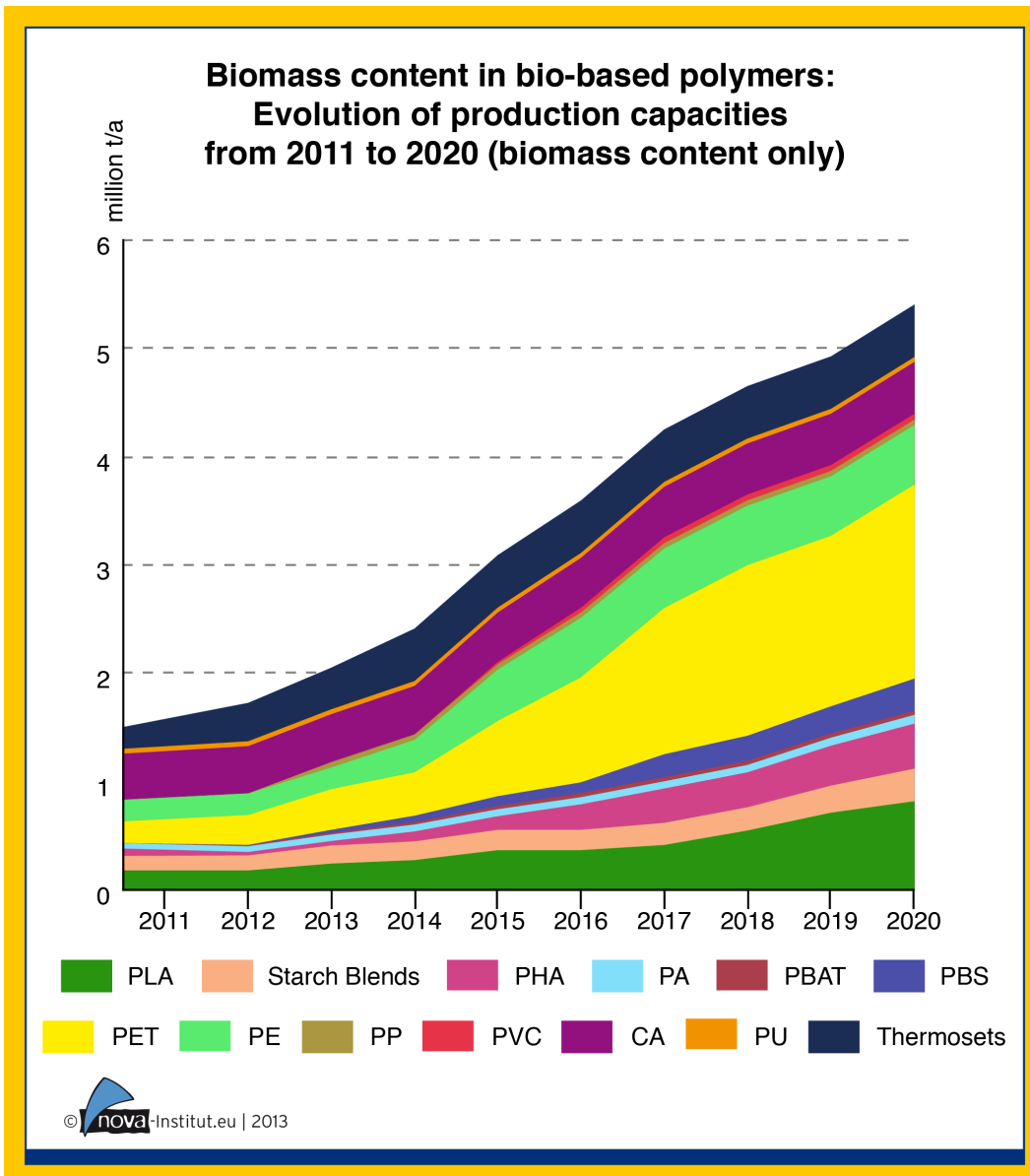


Figure 4: Bio-based polymers: Evolution of production capacities from 2011 to 2020

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.



**Figure 5: Biomass content applied in bio-based polymers: Evolution of production capacities from 2011 to 2020 (biomass content only, see Table 1)**

### *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%.

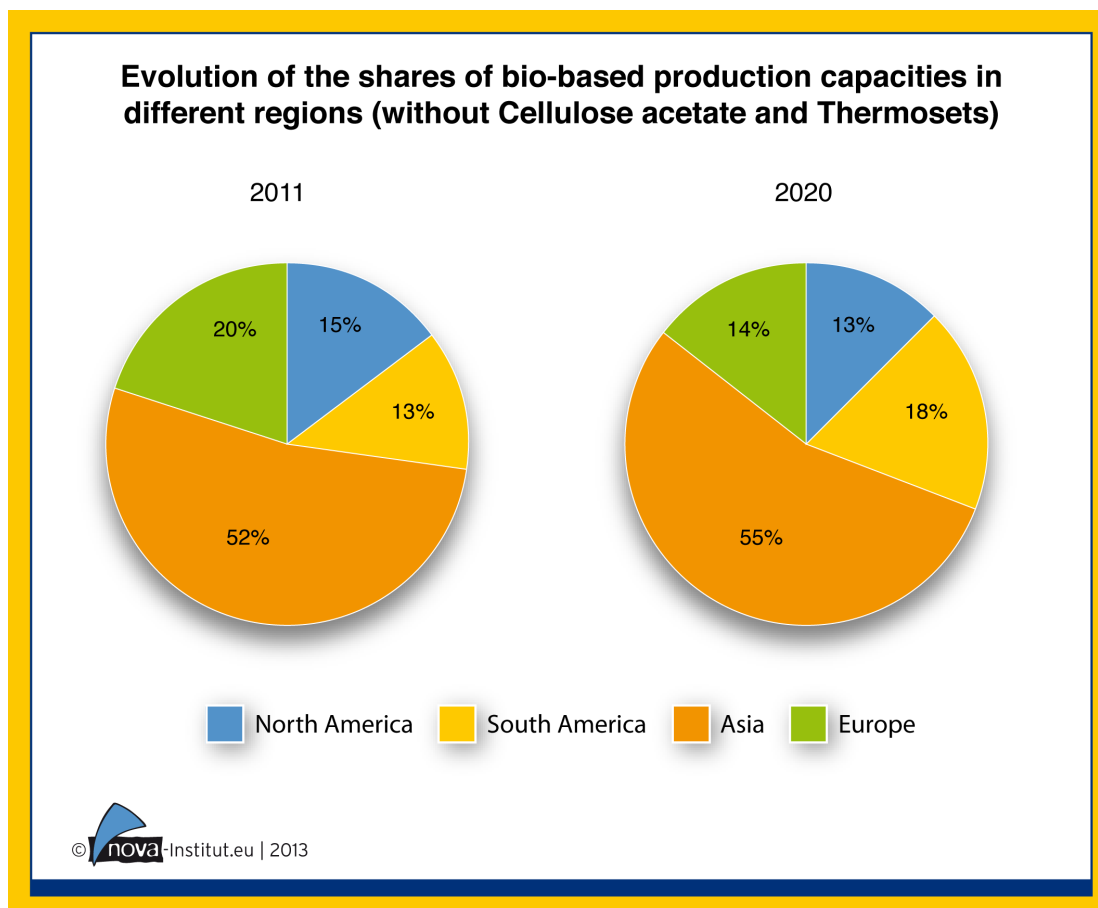


Figure 6: Evolution of the shares of bio-based production capacities in different regions

### *Production Capacities for Bio-based Polymers in Europe – Status Quo and Trends towards 2020*

The study's findings show that Europe's position in producing bio-based polymers is limited to just a few polymers. Europe has so far established a solid position mainly in the field of starch blends (blends of polymers with native starch or thermoplastic starch) and it is expected to remain strong in this sector for the next few years (see Figure 7). Nevertheless, new developments and investments are foreseen in Europe: some years after the installation of industrial scale PLA capacities in North America and Asia, the first European industrial-scale PLA plant is scheduled to become operational in 2014.

PET production is growing worldwide, largely due to the Plant PET Technology Collaborative (PTC) initiative, whose global value chain development will lead to the introduction of future production facilities in Europe by 2015.

One noteworthy finding of other studies is that Europe shows the strongest demand for bio-based polymers, while production tends to take place elsewhere, namely in Asia and South America. The bio-based polymer production facilities for PLA and PHA located in Europe

are currently rather small, and there are next to no production capacity figures for the latter. On the other hand, bio-based PUR and PA production has gradually taken off in Europe and is likely to remain stable in order to supply the growing markets on the building and construction and automotive sectors. Europe does host industrial production facilities for PBAT (shown in Figure 7), which although still fully fossil-based, is expected to be increasingly bio-based reaching shares of 50% by 2020, to judge by industry announcements and the capacity development of its bio-based precursors.

With leading chemical corporations, Europe has a particular strength and great potential in the fields of high-value fine chemicals and building blocks for the production of PA, PUR and thermosets among others. However, only few specific, large-scale plans for bio-based building blocks with concrete plans for the production of bio-based polymers have been announced to date.

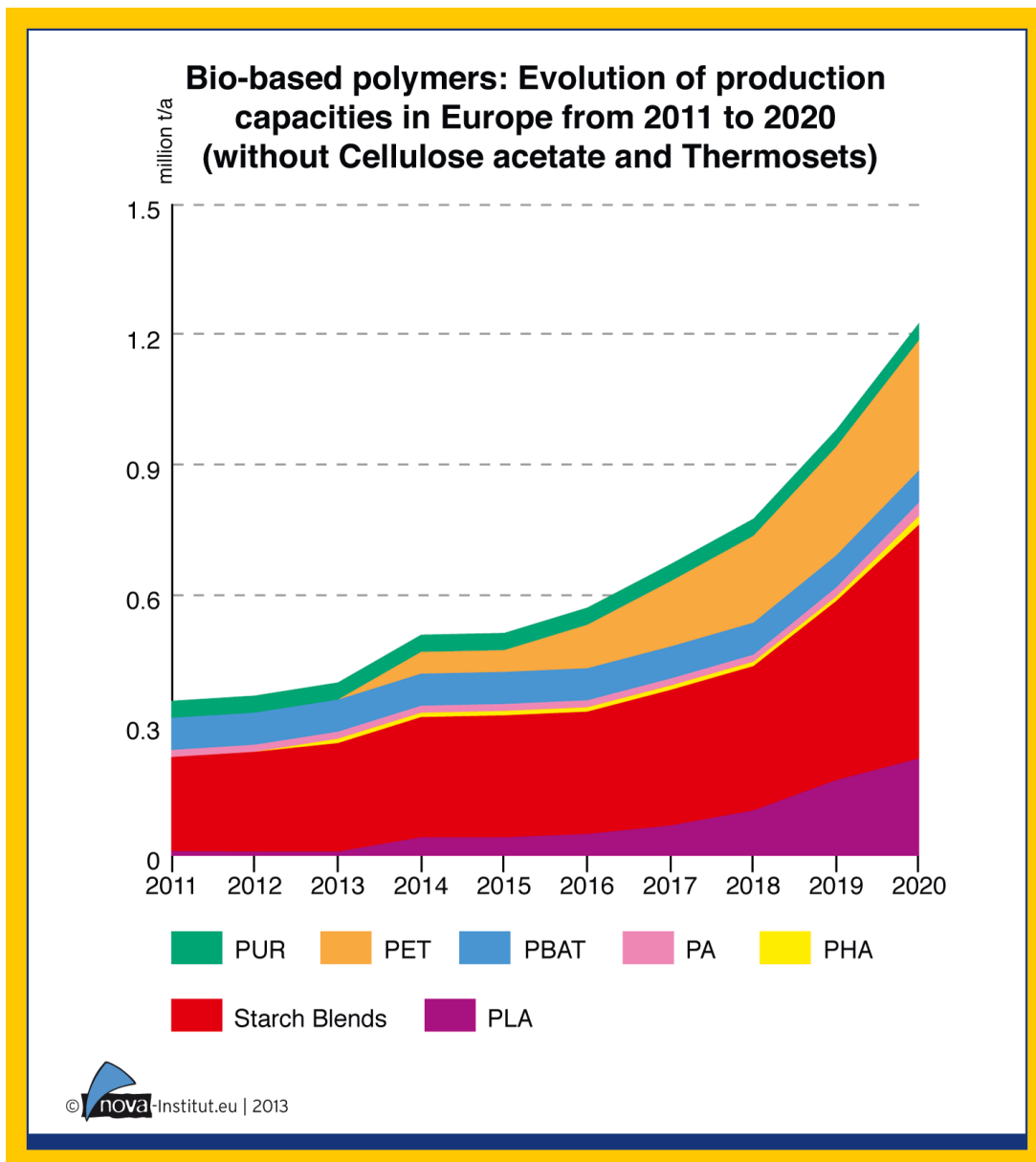


Figure 7: Bio-based polymers: Evolution of production capacities in Europe from 2011 to 2020 (without Cellulose acetate and Thermosets)

### **EU: No dedicated policies to promote bio-based polymers**

The European Union's relatively weak position in the production of bio-based polymers is largely the consequence of an unfavourable political framework. In contrast to biofuels, there is no European policy framework to support bio-based polymers, whereas biofuels receive strong and ongoing support during commercial production (quotas, tax incentives, green electricity regulations and market introduction programmes, etc.). Without comparable support, bio-based chemicals and polymers will suffer further from underinvestment by the private sector. It is currently much more attractive and safe to invest in bio-based polymers in Asia, South America and North America.

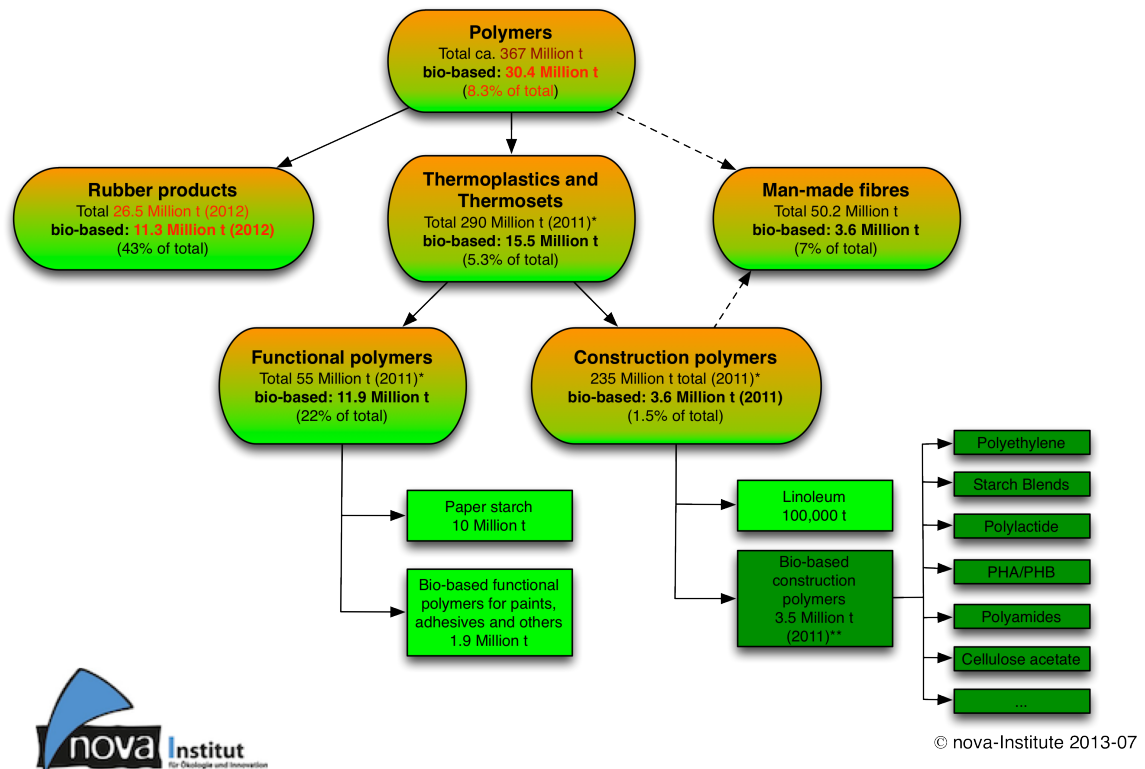
#### **Remark:**

Figure 7 shows the production capacities for bio-based polymers except for thermosets and cellulose acetate. There is a simple reason for this: although good expert estimations of world thermoset and cellulose acetate production capacity are available, based on the global development of their bio-based precursors, it is not possible to break this information down by region.

## 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.

### Polymers world wide, bio-based shares, year 2011 (mostly)



(\*): Data from PlasticsEurope 2012. Original data show 45 Million t functional polymers plus 235 Million t construction polymers = 280 Million t total. We added in addition 10 Million t paper starch to the functional polymers -> new total: 290 Million t.

(\*\*): nova-Institute 2013

plus Different additional sources, like International Rubber Study Group ([www.macplas.it](http://www.macplas.it), 13-07-10).

**Figure 8: 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).

## **2.2 Natural fibre reinforced composites (NFC) in the European automotive industry**

Europe has a long tradition of growing fibre plants for different applications. The technical short fibres that have been produced for a while now by the modern “total fibre line” by several European companies are suitable for many technical non-woven applications. The most important application sector for these fibres is the automotive industry. We have compiled the most comprehensive collection on up-to-date information on the use of natural fibres in the European automotive industry as part of one of our market studies (see Chapter 1).

### **2.2.1 Introduction – methodology and survey**

Since 1996 the nova-Institute has been surveying data on the use of natural fibres (NF) in the German automotive production, now the first European survey was undertaken for the year 2012, based on the same methodology as the surveys before. In the comprehensive investigation by means of e-mail questionnaires and telephone interviews, the data for the year 2012 were surveyed in the first half of 2013. As in previous years, we focused on data of the tier-one suppliers active in Germany and were able to get almost a complete picture – but in contrast to older surveys, also European production data were directly collected. Additional exemplary interviews of employees of automotive companies, NF mat producers, machine manufacturers and raw material suppliers served the purpose of further backing the data and showing the latest trends.

The methodology and history of the previous surveys as well as a discussion of the market data before 2005 is comprehensively presented in Karus et al. 2006.

Almost all data of the 2013 survey prove to be consistent with the surveys of previous years. The amounts of NF composites used in 2012 are almost on the same level as for 2005. Unfortunately, no surveys were conducted between 2006 and 2012. However, in this year’s survey, experts reported a decrease of natural fibre composites after the year 2005, but also new technical developments and innovation on tier-one level. Due to several new projects a slow increase since 2009 was reported and finally between 2011 and 2012 the old level of 2005 was reached again and probably even slightly increased.

### **2.2.2 Natural fibres in the European automotive production – volumes and shares**

The focus of the research was the input of natural fibres by the tier-one suppliers who use natural fibres, natural fibres non-woven mats or granulates to produce natural fibre composites. The most important tier-one suppliers interviewed in the survey were (in alphabetic order): Borgers, Boshoku, Carcoustics, Dräxlmaier, Faurecia, Heywinkel, IAC, JCI, Magna, MöllerTech, Renolit, Rieter, Röchling, Werzalit and a few more. Not all have filled the questionnaire and some smaller ones have left the natural fibre sector, but we were able to obtain a comprehensive picture of the sector. Generally speaking, we see a concentration on some bigger suppliers.

In 2005 (Karus et al. 2006), 19,000 tonnes of natural fibres (without wood and cotton) were used in automotive composites in the German automotive production – after about 12,000 tonnes in 2000. While exotic natural fibres – jute & kenaf, sisal, coir and abaca –

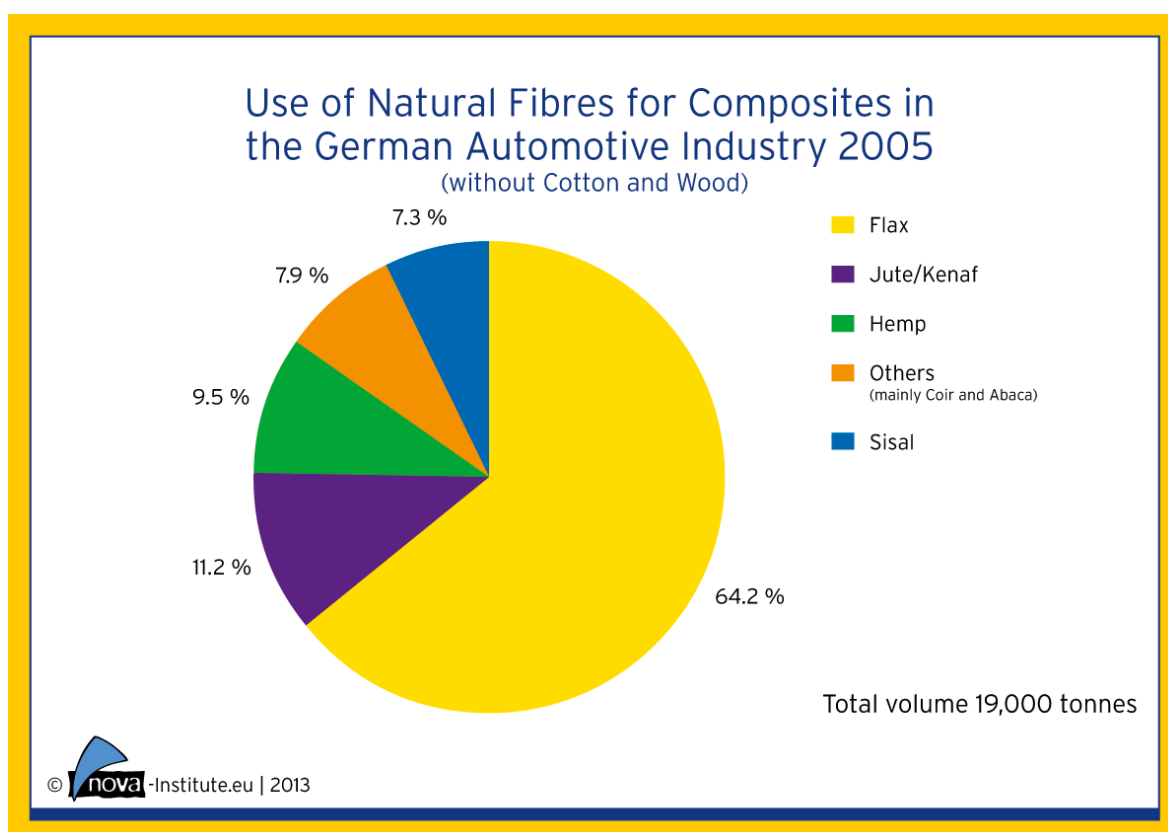
were able to increase their volumes substantially between 2000 and 2004 both on a percentage basis and absolutely, there has been a stagnation ever since.

Experts estimated in 2006 that the German automotive production use about two third of the European natural fibre composites, because of the high share of the German automotive industry and especially the high share in middle and high class cars, which often have a higher amount of natural fibres. That means that about 29,000 t natural fibres were used in the European automotive composite production at that time (except recycled cotton and wood fibres) (Karus et al. 2006).

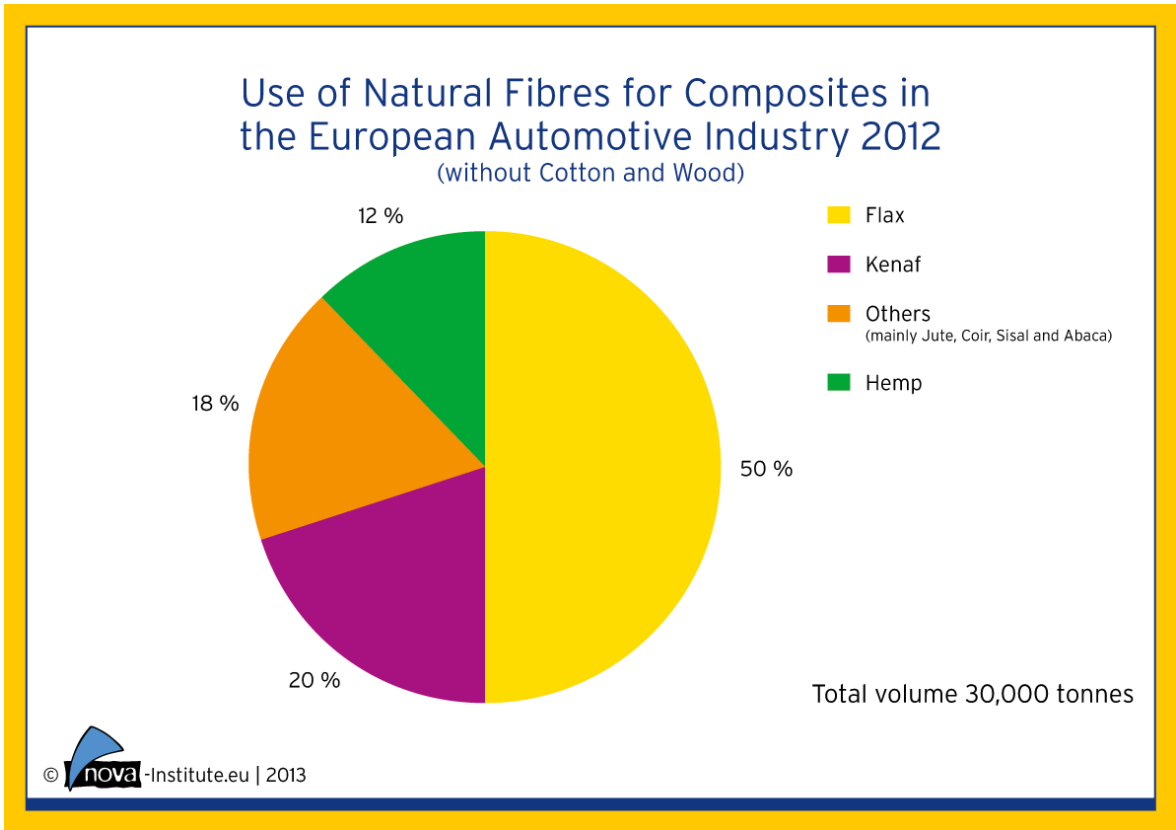
The survey from summer 2013 shows the following volumes for natural fibres in the European automotive production in 2012:

Natural fibres	30,000 t	Mainly passenger cars (flax, kenaf, hemp, jute, coir, sisal and others)
Recycled Cotton fibres	20,000 t	Mainly in lorries
Wood fibre	30,000 t	Passenger cars and lorries
<b>Natural fibres in total</b>	<b>80,000 t</b>	<b>Passenger cars and lorries</b>

The following charts show the shares of different natural fibres in the form of pie charts – for the German automotive production in 2005 (Karus et al. 2006) and for the European automotive production in 2012 (this survey).

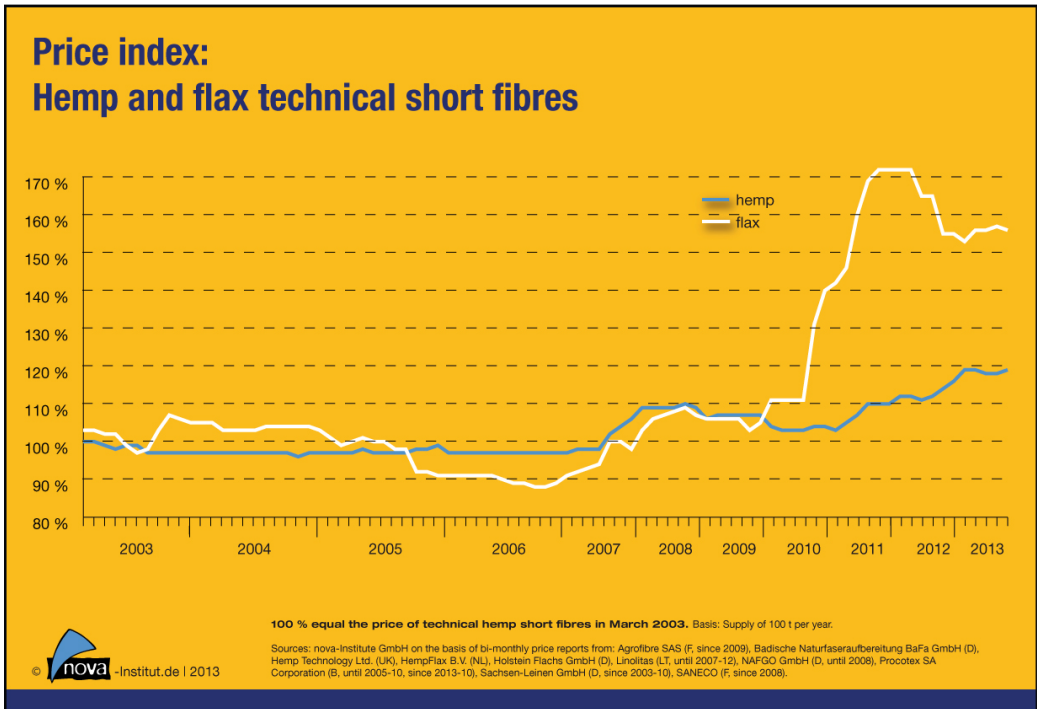


**Figure 9: Use of Natural Fibres for Composites in the German Automotive Industry 2005** (total volume 19,000 tonnes); Karus et al. 2006



**Figure 10: Use of Natural Fibres for Composites in the European Automotive Industry 2012**  
(total volume 30,000 tonnes), others are mainly Jute, Coir, Sisal and Abaca; nova-Institut 2013

The predominance of flax fibres in 2005 (market share of almost 65%) becomes weaker in 2012 (50%). The used short flax fibres are almost exclusively produced in Europe, in most cases as “tow”, a by-product of textile long fibre production. This also means that the fibre price is volatile, depending on the demand of the textile market and especially from Chinese imports. This is the main reason for the decreasing share.



**Figure 11: Price development for Flax and Hemp technical short fibres (suitable for non-woven and composite applications) from 2003 to 2013; nova-Institut 2013**

Kenaf and Hemp have clearly been the winners between 2005 and 2012. In 2005, Kenaf was only among “others”, in 2012 its share is about 20%. Some OEMs decided to switch to Kenaf from Asian origin (Bangladesh, Indonesia). Hemp fibres, almost exclusively from European production, presently bring 3,700 tonnes (Carus et al. 2013) to the automotive market, corresponding to a market share of 12% (2012), compared to 9.5% in 2005.

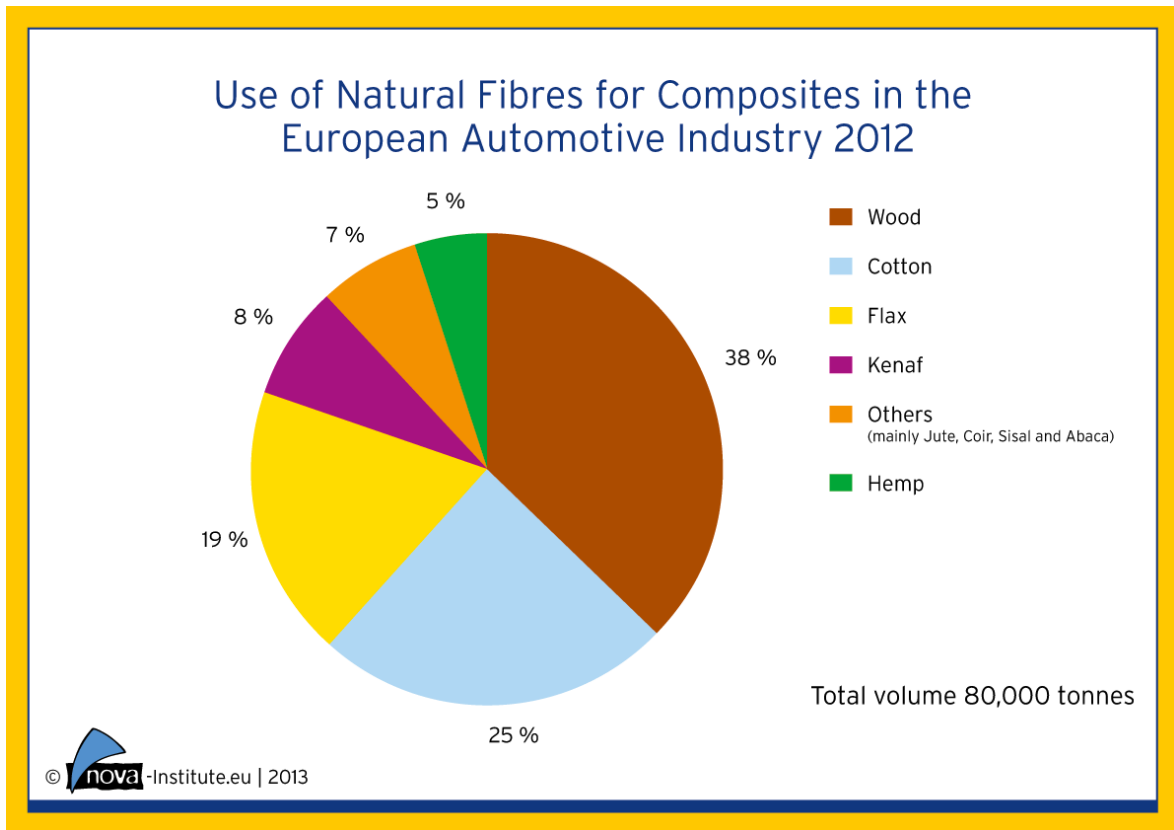
“Today (early 2013) the price range for Hemp fibres lies from about 50 Eurocent/kg for the cigarette paper industry (ca. 25% shiv content) to around 75 Eurocent/kg for automotive and insulation (2-3% shiv content).” (Carus et al. 2013).

For the year 2012, it was possible to itemise “others”, which had not been feasible in recent years due to the lack of respective data. The most important other fibres are – in this order – Jute (7%), Coir (for automotive seat upholstery), Sisal and Abaca with show together a market share of 18%.

While jute is by far the fibre with the highest turnover worldwide, thus being the “leading fibre” amongst technical natural fibres, it is not in the European automotive sector. In the trade sector, jute and kenaf are often not properly differentiated from one another. Sisal is the second most important technical natural fibre world wide, mainly coming from Africa and South America. Due to high prices of Sisal fibres over the last decade, the share in the automotive sector is decreasing. The main reason is high demand from other sectors like construction and grinding.

The next graph also includes recycled cotton fibres (mainly for lorries) and wood fibres, to give the full picture for all natural fibres. The wood fibre composites used in the automotive industry that are fabricated through compressing moulding, have a large fibre content and an almost exclusively thermoset matrix. Thermoset cotton composites are almost exclusively used in lorry driver's cabs. More detailed information on typical applications can be found below.





**Figure 12: Use of Natural Fibres for Composites in the European Automotive Industry 2012, including cotton and wood (total volume 80,000 tonnes), others are mainly Jute, Coir, Sisal and Abaca; nova-Institut 2013**

### 2.2.3 Which developments can be expected for fibres in the coming years?

Will kenaf and hemp continue to increase their shares? The factors for success are very different for the two plants. The growing demand for kenaf originates mostly from the explicit wishes of some OEMs to use kenaf as a globally uniform fibre. However, this wish leads to a number of problems: In terms of processing, kenaf is not ideal, as reported repeatedly by non-woven producers. Fibre losses are high.

Also, the desired qualities can only be obtained by water retting, which has negative ecological (biochemical oxygen demand of the retting water) and social (mostly working conditions and wages) impacts in the fibre producing countries, e.g. Bangladesh, India or Indonesia. A sustainability certification of Asian natural fibres does not seem likely to be implemented in the nearer future.

Trials to produce kenaf fibres with a modern total fibre line have not been successful so far, although this does not mean that it is impossible. Currently, there are trials in Malaysia for example. However, even if this becomes feasible and ecological and social improvements can be expected, there will still be problems with the fineness, shive content and the regularity of the fibre. These factors can only be satisfactorily reached with water retting or modern enzymatic or biochemical processes (see below for hemp). The latter have not been established so far due to technical and economic problems.

Especially the quality of the water-retted kenaf fibres make them interesting for the automotive industry, since that makes it possible to use very thin lamination, which are desirable for design and weight reasons.

Kenaf fibres are not easy to tell apart from jute fibres, and it is not always sure that jute fibres might not be contained in a bale labelled “kenaf”. Jute fibres are produced at a much higher volume than kenaf and their bad reputation is not justified. It stems from the “batching oil” that is used in the textile process chain, which makes the fibres more flexible and it also used for other types of natural fibres. These fibres, treated with batching oil, are not acceptable for the automotive industry due to the fogging problems. However, if jute fibres are employed that are free of batching oil, there is no fogging and they can be processed just as well as kenaf, sometimes even better.

The continued success of kenaf fibres is mostly dependent on the future decisions of the OEMs. It is hard to find globally available fibres that possess a high grade of fineness and a low shive content, are affordable and are produced under good ecological and social conditions. One has to make compromises in some way or another. Hemp is some sort of opposite of kenaf – so what is more important, an ecologically and socially acceptable production or a thinner lamination?

**Hemp fibres** are not globally available. Currently, they are mostly cultivated in Europe (with potential for extension) and some qualities also in China. Should the setup of a hemp industry in Canada and the U.S. be successful, this will change.

Hemp fibres from Europe (and probably in the future from the U.S. and Canada) are produced in a total fibre line, in a modern and techno-economic optimised processing line.

With this technology, it is possible to produce a technical short fibre under high ecological and social standard at the same price level of Asian imports. A sustainability certification is being worked on and should be easy to obtain.

The price being paid for these advantages is limitations in terms of fibres fineness, regularity and a residual shive content. This means that press-moulded parts can be easily produced at a high quality, but they possess an irregular surface structure, which does not allow for very thin laminations. A somewhat thicker lamination is unavoidable.

To solve the problems of irregularity, additional treatments such as steam explosion, ultrasound or different chemical or enzymatic processing could be feasible approaches. These very modern processes have not been established so far, mostly due to cost reasons. The fibre qualities could be even better than those obtained by water retting, but the prices are much higher. Without a clear commitment by OEMs, a production for automotive applications is not to be expected,

**Flax fibres** will continue to play a dominant role, since a large amount of technical short fibres will always be created as side-products (tow) of the long-fibre textile production, which can be sold at an economic price at relatively good quality. The only disadvantage is: If the fashion year is successful, the textile industry also requires more short fibres, in order to cottonize them and process them together with cotton. In cycles, this leads to scarcity and a significant increase in prices. This problem will continue to exist and maybe lead to a slight decrease in use of flax fibres.

**Jute** could indeed become an important natural fibre for the automotive sector. Volumes and logistics are at a high level, but the fogging problem has damaged the reputation of jute quite thoroughly. It would be easy to obtain large volumes of batching-oil free Jute fibres, especially since the processing capacities are often above the demand from the mostly decreasing traditional applications. However, the ecologically and socially questionable water retting and the lack of a modern processing technology remain to be problematic.

**Sisal** is being used less and less in the automotive industry for cost reasons. The production capacity is limited and demand from the construction sector, especially from the Arab

world is increasing. As long as the fibres remain scarce, the achievable market prices are too high for the automotive industry.

With the further decline of the European textile industry, the recycled cotton fibre will decrease in availability and probably also get more expensive. It is therefore expected that the use of these fibres will tend to decrease.

### *Conclusion natural fibres*

The good news is that kenaf, jute, flax, hemp and also sisal are all well suitable to be used as technical natural fibres in press-moulded parts for the automotive sector. The question of which types of fibres will seize which market shares, is mostly dependent on the decisions of the OEMs. Here, availability, prices and qualities play a part and in the future probably also ecological and social aspects. Sooner or later, all renewable resources in the automotive sector will have to provide a sustainability certification. The low price level of water-retted kenaf and jute fibres will not be tenable.

## **2.2.4 Main applications of natural fibres in automotive composites**

The following table shows the results of an additional questionnaire we did in the summer of 2013. We asked the tier-one suppliers about their production shares of natural fibres, recycled cotton and wood for different car parts.

The following table shows that Wood-Plastic Composites are mainly used for rear shelves and trims for trunks and spare wheels as well as for interior trims for doors. Natural fibre composites have a clear focus on interior trims for high-value doors and dashboards. Cotton fibres are used for trims for trunks and spare wheels as well as for the underbody.

We see almost no natural fibres, cotton or wood in trims for pillars (A, B, C) and in roof-liners – because of the property or processing limitations.

**Table 3: High (++) and important (+) share of listed materials in selected automotive interior applications (nova-Institut 2013)**

	Interior Trim for Doors	Trim for Pillars (A, B, C)	Roof-liner	Dash-board	Rear Shelf	Trim for Trunk / Spare Wheel	Under-body
Pure Plastic (plus mineral filler)	++	++		+	++	++	+
Wood-Plastic Composites	+				++	++	
Fibreglass Reinforced composites	+		++	++			++
Natural Fibre Composites	++			+			
Cotton Reinforced Composites						+	+

### *Why are natural fibre composites used in the automotive industry?*

There are different reason for using natural fibre composites in automotive applications, often mentioned by experts from OEMs and tier-one suppliers:

- Easy and cost-efficient processing of materials with a resilient formula and long know-how
- Weight reduction (up to 30%)
- Price competitive
- Good accident behaviour (good energy absorption (side impact), no sharp edges)
- Good mechanical and acoustic properties
- Low fogging
- No creaking on contact
- Flame resistant – slow burning speed
- High bio-based share (non-food crops)

Summing up, Bächtli 2012 wrote:

“There is a diversity of reasons for the use of natural fibres: Advantages in the ecological footprint, affordable production costs as well as good acoustic and mechanical properties. Furthermore, natural fibre reinforced plastics convince with their low weight. They enable savings in mass of up to 30 % - which is a decisive plus in times of lightweight construction. ... ,Natural fibre composites have been and are still further developed in terms of lightweight construction and strength. They have become integral parts of the automotive industry.’ (Werner Klusmeier, JCI).“

## **2.2.5 Volume and shares of different production techniques**

As shown above, about 30,000 tonnes of natural fibres were used in the European automotive production in 2012. Based on the natural fibre shares that were confirmed in several surveys (see Table 5) and an assumed average edge trim of 15 % (with compression moulding), the following amounts of natural fibre composites arise: Around 60,000 t of biocomposites were produced from 30,000 tonnes of natural fibres (see Table 4). 95 % of the production technique is compressing moulding, 55 % with thermoplastics and 45 % with thermosets. Only about 5 % of the amount is used in all other processing techniques such as injection moulding, extrusion, press flow-moulding, RTM and others. Especially for injection moulding, the forecast has been much higher previously – but could not be reached. PP-NF granulates could not reach sufficient physical properties, price levels and supply security so far to convince the automotive customers.

For wood, the processing techniques are quite different. 50 % of the 60,000 tonnes wood-based composites are produced with compression moulding; here the share of thermosets is very high. But also extrusion in combination with thermoforming has a share of 45 %. Although some promising developments are appearing (see below), today the volume of WPC granulates for injection moulding is still very small.

Recycled cotton fibres are mainly used in thermoset compression moulding for big lorry cabin parts. With a further decline of the European textile industry, the availability of recycled cotton fibre will also decrease.

**Table 4: Biocomposites with natural fibres, wood fibres and recycled cotton in the European automotive production in 2012**  
**volume of fibres, composites and shares of processing technologies; nova-Institut 2013**

Biocomposites	Volume fibres in tonnes in 2012	Volume biocomposites in tonnes in 2012	Processing technologies	Matrice
Natural Fibres Reinforced Plastics	30,000	60,000	95 % compressing moulding, 5 % injection moulding & others	55 % thermoplastics, 45 % thermosets
Wood-Plastic Composites	30,000	60,000	45 % extrusion & thermoforming, 50 % compression moulding, 5 % injection moulding & others	Extrusion: 100 % thermoplastics, compression moulding: > 90 % thermoset
Recycled Cotton Reinforced Plastics	20,000	30,000	mainly compression moulding	> 90 % thermoset
<b>Total</b>	<b>80,000</b>	<b>150,000</b>		

In 2006 it was often said that natural fibre compression moulding has passed its peak, already being on a downswing. The 2006 survey seems to confirm this, but merely detects a stagnation. However, a shift among suppliers is noticeable that could explain the impression: While, indeed, the production of NF compression-moulded parts is quantitatively decreasing among many small and medium suppliers, the production is accordingly increasing among a few large suppliers, thus compensating the decrease among smaller suppliers.

For 2012 we found that compression moulding still completely dominates the technologies being employed, especially in non-wood applications. It is an established and stable processing technique. However, a further growth is limited because of the crisis of the European car industry.

For wood-based composites we see a relevant share in extrusion & thermoforming and even injection moulding could become stronger due to some recent developments (see Table 5 below).

The following table shows the natural fibre shares for different production techniques from the different older surveys, mostly confirmed by the new survey. These shares were used in combination with an assumed average edge trim of 15% (with compression moulding) to calculate the volume of biocomposites from the volume of the fibres.

**Table 5: Typical ranges of natural fibre shares for different production techniques; nova-Institut 2013**

Automotive Processing Technology	Share of Natural / Wood Fibres in Biocomposites Typical Ranges
Press Moulding: Natural Fibre & Thermoplastic	40 – 50 %
Press Moulding: Natural Fibre & Thermoset	50 – 70 %
Press Moulding: Wood Fibre & Thermoset	70 – 90 %
Extrusion: Wood Fibre & Thermoplastic	30 – 40 %
Injection Moulding: Natural Fibre & Thermoplastic	30 – 40 %

## 2.2.6 Natural fibres per passenger car

In the EU, 15.7 million passenger cars were produced in 2011; in addition, 2 million other motor vehicles (incl. trucks, transporter, motor bikes, etc.) were manufactured. In average,

considering that 30,000 tonnes of natural and another 30,000 tonnes of wood fibres are used in 15.7 million cars, every passenger car in Europa contains 1.9 kg of natural fibres respectively 1.9 kg wood fibres.

For 2004 and 2005, an average of 3.6 kg natural fibres (without wood fibres) per passenger car was reported for the German automotive industry, after 3.5 kg in 2003 (Karus et al. 2006). Since the German automotive industry is the most important consumer of natural fibre parts within the European automotive sector, and since natural fibres are more used in middle- and high-class cars, the figures of 1.9 kg for the European average and 3.6 kg for the German average match well.

Already today, some passenger cars contain up to 43 kg natural and wood fibres composites per vehicle, see the following table:

**Table 6: Mercedes-Benz, volume and number of parts from natural and wood fibre composites, Mercedes-Benz 2007**

Model	Volume of natural and wood fibre composites in kg per vehicle	Number of parts from natural and wood fibre composites
A and B class	33	26
C class	22	33
E class	32	50
S class	43	27

A value of 30 kg natural and wood fibre composites per passenger car in Europe could take as state of the art, which means about 20 kg natural and wood fibre per passenger car, which is more than five times more than used to day (3.8 kg natural and wood fibre per passenger car). The potential is even higher, up to ten times.

### 2.2.7 Future developments

Regarding the future market development of natural fibre reinforced composites, there presently is no clear trend noticeable. Estimates differ widely from each other within the automotive branch. On the one hand, there is the belief that natural fibres have already passed their peak and their applications will decrease (as happened after 2005), and on the other hand that there is a stabilisation with a new market growth (since 2009) and interesting potentials in the medium term. “No clear direction for NF materials: Successes in the past, weakening at the moment, and an interesting future” – this is how an insider summarised the current situation in the summer of 2006 – and seven years later in 2013, the situation is not so different. Natural fibres compression moulding with improved properties (lower area weight) could expand again to the level of 2005 and perhaps even further. But other technologies could not meet the expectations, especially natural and wood fibre injection moulding remains on a low level.

The material choice of OEMs and tier-one suppliers is hard to assess, depending on the series of models, decisions pro and contra natural fibre reinforced composites are made at the same time. It is clearly noticeable that the setting for new materials has substantially changed in recent years. Under heavily increased cost and market pressure for which also quality is partly sacrificed, new materials have had considerably more difficulties than before. Suppliers want to use existing processing lines to capacity and not invest in new machines. New materials should be better and cheaper, which can hardly be achieved.

From an economic point of view, NF and wood materials exhibit decent price stability, being less dependent on the mineral oil price than other materials, particularly if large NF and wood shares respectively can be realised. Were CO<sub>2</sub> emissions, which are caused by

the material – during production and usage – taken more seriously into account, natural fibre compression moulded parts could realise additional significant benefits. In several life cycle assessments, NF composite materials showed very good results. Less energy is used for the production and due to lightweight construction, even fuels are saved during the use phase.

### *Compression moulding*

NF compression moulding is an established and proven technique for the production of extensive, lightweight and high-class interior parts in medium and luxury class cars. Advantages (lightweight construction, crash behaviour, deformation resistance, lamination ability, depending on the overall concept, also price) and disadvantages (limited shape and design forming, scraps, cost disadvantages in case of high part integration in construction parts) are well known. Process optimisations are in progress, in order to reduce certain problems such as scraps and to recycle wastage. By means of new one-shot compression moulding presses, also soft surfaces can be directly integrated, which has not been possible so far with injection moulding.

As far as preferably inexpensive door concepts with a high part integration are concerned (up to the point of doing without lamination), NF compression moulding does not have good chances against injection moulding. As far as medium- and high-class door concepts are concerned, NF compression moulding remains to be a first choice technique, more and more also in the non-German automotive sector. The decreases among small and medium suppliers are presently fully compensated by increases among large tier-one suppliers. A structural problem is the fact that there are only a few compression moulding machine manufacturers and mat producers and that compression moulding is a specialised technique (dependence!). The suppliers would preferably use their existing (injection moulding) lines to capacity. Under heavy price pressure, this can become a disadvantage for NF compression moulding presses. For new investments, compression moulding is cheaper up to 100,000 party a year. For higher scales, injection moulding will take over.

The future of NF compression moulding depends on numerous factors (price pressure, strategies, and interior concepts of the OEMs and suppliers, mineral oil market, plastics and glass fibre prices, progress of compression moulding as well as correction concepts and materials respectively). We assume that this technique will keep markets and even will find new markets. This is also indicated by the fact that presently more NF compression moulding lines are being installed worldwide than ever before – not in Europe, but in China, India and Iran. There, in view of the current world market prices for natural fibres, NF compression moulding seems to be regarded as economically interesting and seminal technique.

Since 2009, new improved compression moulded parts have shown impressive properties in weight reduction. This is one reason for the increasing interest in new car models. Typical plastic parts, also glass fibre reinforced plastic parts, show area weights of above 2,200 g/m<sup>2</sup>. A typical thermoplastic NF composite in compression moulding can achieve easily 1,800 g/m<sup>2</sup>. New developments show that with using the bonding agent MAPP (normally used in injection moulding only), the area weight can be reduced even to 1,500 g/qm.

Using thermosets, the values are even lower. Today, 1,400 g/m<sup>2</sup> and lower are easily reachable with for example Acrodur® from BASF. The target is 1,000 g/m<sup>2</sup>, some experts think even 800 g/m<sup>2</sup> might be possible in the future. This is less than half of the area weight pure plastics or glass fibre reinforced plastics can offer. Only carbon fibres reach those area weights. But these are at a completely different price level.

With Acrodur®, another thermoset entered the market after epoxy and PU resins and has already been able to expand the applications. It is an Acrylic binder for fibre bonding and high-fibre composites moulding, which can already be found in different high-value BMW vehicles.

“Acrodur is a green, zero-emission acrylic thermoset resin for fibers and particles. This high-performance, lightweight, cost-effective and green composite saves costs and significantly reduces volatile organic compound (VOC) emissions. As a formaldehyde-free binder with all its properties and advantages, Acrodur is an ideal thermoset material for demanding and emissions-critical processing and applications, whether in abrasive nonwovens for household and industrial purposes or nonwovens for automotive and filter applications.” (<http://www.acrodur.info/home.html>)

BASF recently demonstrated a prototyping line for a woven kenaf and foamed water based Acrodur acrylic latex binder resin biocomposite. The materials were then put in a radio-frequency dryer. BASF is pushing to get the US automotive industry to use the biocomposite. The production line is part of BASF’s Wyandotte R&D centre. Henning Karbstein was quoted stating, “It comes down to cost and performance for the automotive industry... The environmental benefits are icing on the cake.”

Summing up: With an increasing interest in robust, low cost and lightweight construction, natural fibres compression moulding is a very interesting and attractive technology with a potential to grow.

### *Extrusion and thermoforming*

Extrusion of WPC with follow-up thermoforming to the final WPC car part is only used by a very limited number of tier-one suppliers with a specific processing infrastructure. Whether this is a real alternative to compression moulding cannot be evaluated because of missing data on the economy of the process. With the one-shot technology, compression moulding can be used as a one-step process, whereas extrusion and thermoforming is already a two-step process followed up by additional steps for the surface treatment (mostly lamination).

### *PP-NF injection moulding*

There are big differences in the estimation of market developments in the field of PP-NF injection moulding. Some people do not see any relevant application of PP-NF in motor-cars, neither their technical data nor prices were attractive, others attest PP-NF large growth rates and a big potential. This especially applies to the material WPC with wood flour and fibres.

NF granulates and their processing are often regarded as not yet mature and too expensive, in addition, there are complains that there are no established, bigger suppliers with respective support yet. Should these problems be solved, there seems to be real interest among OEMs and suppliers. However, PP-NF granulates will only become interesting with increasing mineral oil and glass fibre prices – both is not really expected in the next years.

The different estimates are partly due to the fact that the current market of PP-NF granulates is very confusing and the various granulates can differ in their mechanical properties and prices at a factor of up to 2. Many potential customers do not know the presently biggest and best suppliers.

During the last two years, new and very interesting developments took place. The wood-working giant Sonae from Portugal, together with Scion, a well established research institute from New Zealand, developed WoodForce®, a special grade of MDF fibres suitable for injection moulding. The composites show very good properties similar to glass fibre



composites, lower area weights and a low price. Also Sonae can deliver high amounts of these wood fibres giving the tier-one suppliers a secure supply. The market introduction started in 2012 and first products are already placed on the market.

Future developments will show whether WoodForce® will be able to overcome the existing barriers for WPC injection moulding and become a success story.

### *Political framework for automotive manufacturing*

A favourable political framework could help biomaterials experience considerable growth. For example forced measures for the reduction of CO<sub>2</sub> emissions are to be mentioned here. In this sector, particularly natural fibres can score well, the production of which is ten times less energy-intensive than that of glass fibres.

A revision of the EU End of Life Vehicles Directive could also have a big influence. If attempts were successful to achieve a renewable resources deduction at source such as e.g. the steel quota, as representatives of the natural fibre branch have been claiming for years, there would be considerable advantages for natural fibre reinforced composites. A practical solution could be that the actual share of renewable resources is credited to each vehicle as material recycling – regardless of whether the part is used energetically or materially. This approach would be justified by the fact that even in the case of burning the renewable resources shares, the CO<sub>2</sub> balance would almost be neutral.

Right now, as our survey showed, this would merely result in about 4 kg natural and wood fibres per vehicle in average in Europe; but vehicles with considerably larger amounts of 20 kg natural and wood fibres have been successfully produced in series for years and could credit these amounts in the future, according to the model mentioned above. A respective revision of the End of Life Vehicles Directive would cost Brussels or the member states nothing and would have crucial steering effects.

If the political frameworks would make the use of natural fibres more attractive, biocomposites and natural fibres could really become a great success story. Also directives setting a maximum gas usage per mileage can favour natural fibre reinforced composites, since they make the cars lighter and therefore help to save gas. In the U.S., the new fuel efficiency standard requires automakers to manufacture cars with an average fuel economy of 54.5 mile per gallon (approx. 22.5 km per litre) by 2025, which would almost double the current standard (New York Times 2012). In the EU, the goals are set by average CO<sub>2</sub> emission values, which are: the fleet average to be achieved by all new cars is 130 grams of CO<sub>2</sub> per kilometre (g/km) by 2015 – with the target phased in from 2012 - and 95 g/km by 2020 (EU Commission 2013b).

Any incentive for the use of natural and wood fibres in the European automotive industry could help to extend the existing amount of 30,000 t/year for each natural and wood fibres, up to five times, that means to 150,000 t/year each – the technologies are ready to use. A great potential for biocomposites!

In fall 2013 FAO published its “Forest Products Annual Market Review” (FAO 2013) with an interesting outlook on wood and natural fibre composites world wide: “Another example of simple replacement of a traditional product by a wood-derived one is in the automobile industry where the quantity of natural fibre composite per car is now estimated at 16 kg, resulting in an estimated 1.5 million tonnes market for natural fibre composite by 2017.” This is well in line with our estimations above.

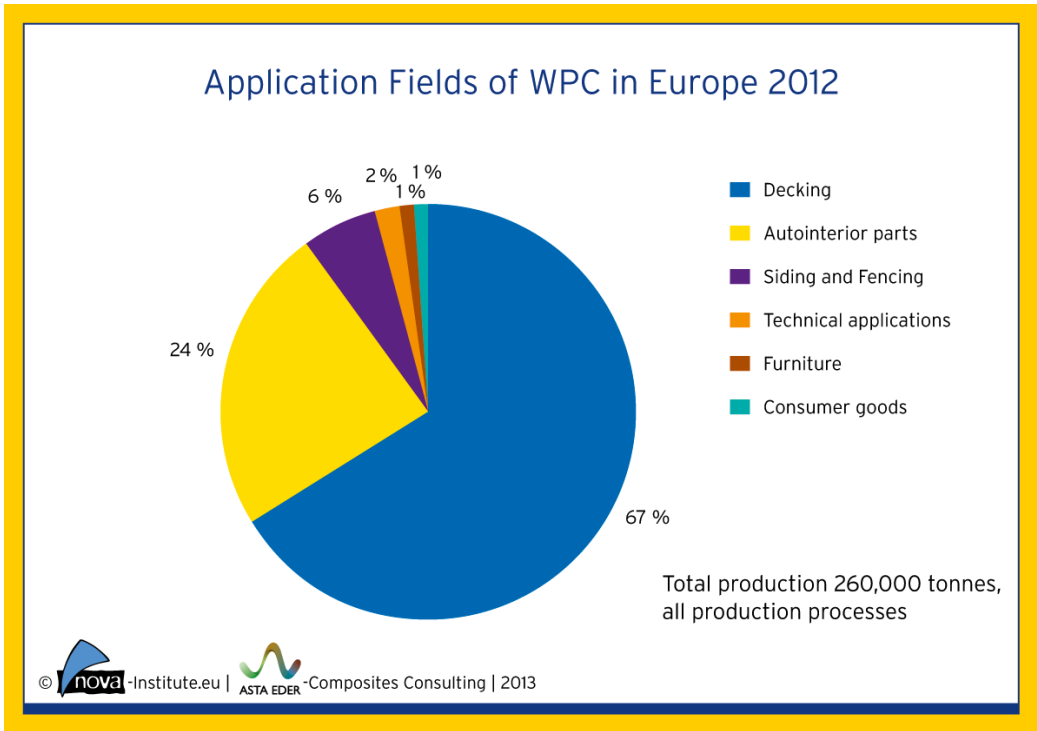
## 2.3 Wood-Plastic Composites (WPC)

This chapter looks at the production of WPC in Europe and worldwide. In the chapter above, WPC was mentioned as one natural fibre composite that is used for the automotive industry. But the total production of WPC covers many other application fields, too.

The total volume of WPC production in Europe was 260,000 tonnes in 2012. The level of market penetration of bio-based composites varies between different regions and application fields. Germany leads in terms of number of actors as well as in production figures. The typical production process in Europe is extrusion of a decking profile based on a PVC or PE matrix. The increasing market penetration of WPC has meant that WPC volumes have risen strongly and that today, Europe has reached a mature WPC market stage. This study predicts growth especially in the German-speaking area on the back of a recovery in construction, especially in renovation, and a further increase of WPC share in the highly competitive decking market. Also, variations of WPC decking models, such as capped embossed full profiles or garden fencing are on the rise across Europe.

The development in shares of applications points to a direction where WPC is increasingly used for applications beyond the traditional ones such as decking or automotive parts. For example, WPC is increasingly used to produce furniture, technical parts, consumer goods and household electronics, using injection moulding and also other processes than extrusion. Also new production methods are being developed for extrusion of broad WPC boards.

Figure 13 shows the different application fields of WPC produced in Europe. The decking market is leading with 67% (mainly extrusion), followed by automotive interior parts with 23% (mainly compression moulding and sheet extrusion as well as thermoforming). Although still smaller, siding and fencing as well as technical applications (mainly extrusion) and consumer goods and furniture (mainly injection moulding) are showing the highest increase in percentage.



**Figure 13: Application fields of WPC in Europe in 2012**

The following picture shows the allocation of the production in different European countries / regions. Germany leads in terms of actors and production figures, followed by the Benelux region and France. The reasons behind the German success in WPC production can be found in a regional concentration of WPC know-how with machine producers and R&D institutes. But also well-educated consumers play a role who have more knowledge about WPC than the European average. Also Germany is one of the few European countries that hosts an official association for WPC producers as part of the wood working association. The success might also be connected to governmental support activities and to WPC conferences that have a very broad information impact in the region. Also the good economic situation in the region has pushed WPC during the last decade in Germany.

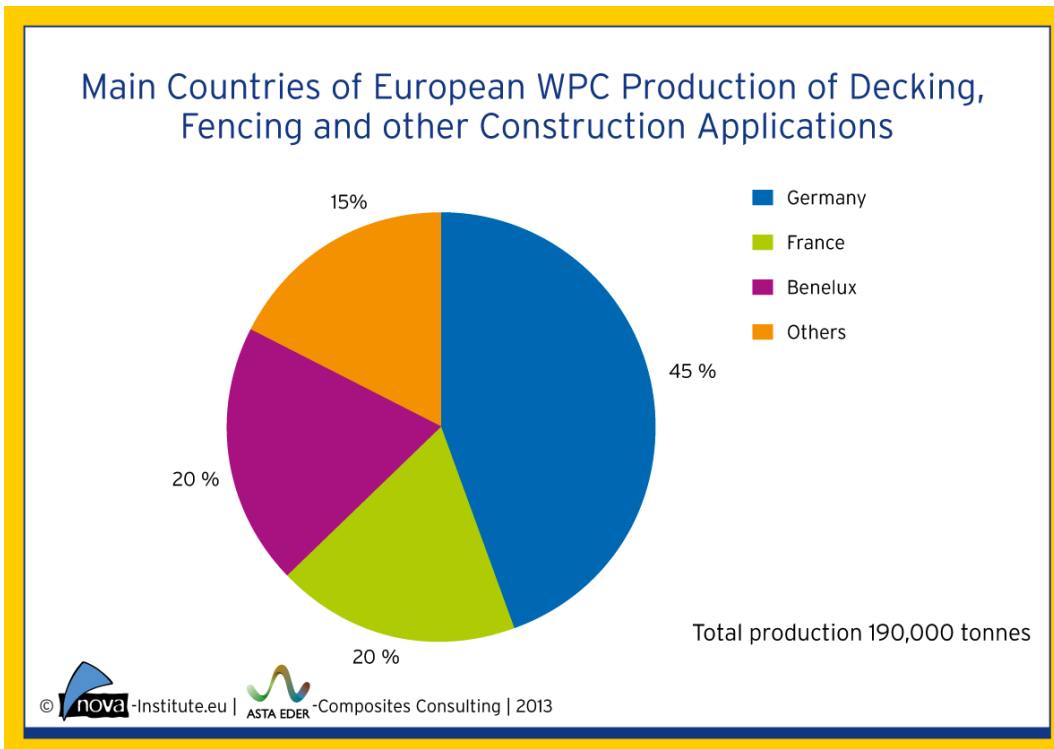


Figure 14: Main countries of European WPC production of decking, fencing and other construction applications

Also France has done a lot to inform the potential WPC producing companies, but the market has stayed more dependent on imports there. Also the Benelux region has a long tradition and knowledge in WPC: As one of the first WPC decking producers and one of the oldest European compound producers Beologic had their market launch in the region 13 years ago. Other European countries in this survey include Scandinavia, Austria, Switzerland, Italy, UK, Spain and Portugal. In total, WPC production can be found in 21 European countries.

An average WPC producing company produces about 3,000 tonnes per year, the big ones produce more than 10,000 tonnes. The total European WPC capacity is estimated to be larger than the production estimated above, so the producers have the possibility to respond to growth in the market demand. Not only production but also the import has been growing substantially during the last 7 years, which shows that the market demand has to be larger than the production. According to the interview results, the share of imports ranges from 20 % to 50 %, depending on the region.

### *WPC innovation trends in Europe*

Product differentiation is used by businesses to achieve and maintain competitive advantages. This can be used if the target customer segment is not price-sensitive. In the case of the WPC company NOVO-TECH, which claims to be one of the biggest WPC companies in Europe and is one of the few ones that are totally dedicated to WPC production, this is achieved with an own tooling unit, which eases the innovation possibilities of the enterprise. The company launched, as the first European WPC producer, an extra-wide (245 x 25 mm) and solid "Jumbo" board made of 75% wood-filled PP with fully encapsulated wood fibres. This WPC board has reached the highest WPC price in Europe (170 Euro /m<sup>2</sup>), this is more than double of the average price level that ranges between 40 and 80 Euro/m<sup>2</sup>.

### *European decking market trends in 2012*

Demand for timber decking is largely driven by the natural look and feel of wood as well as being relatively cheaper to use for restoration of outdoor spaces than hard landscaping with stone and concrete, which still has the biggest market share of the total terracing market. In recent years we have seen WPC becoming increasingly common. This is largely due to the fact that consumers consider WPC to be better than natural wood in terms of colour stability, lifetime and splinters. On the back of the trend of consumer disaffection with timber decking and its maintenance, the share of WPC in the decking market has been continuously increasing and accounts for 2 % to 15 %, depending on the European region.

In Europe, the market for WPC is still relatively new and the level of penetration varies significantly. The construction downturn in Europe has been less severe than in the US and the rising penetration of the market with WPC has meant that WPC volumes have risen strongly until 2009 and even in 2010 some growth could be seen. In 2012 producers faced a decline in demand. Growth in the WPC demand had continued at double-digit rates for almost a decade.

The most important distribution channels are the wholesalers because they are at the hub of the distribution system. Furthermore they account for a high proportion of the imports that come into Europe. Imports into Europe are estimated to account for between 20 % and 50 % of the market demand, but they are still increasing. The primary sources of supply are Chinese producers, which are still mostly offering low-price products and US companies, which have the economic advantages of economies of big scale and a weak dollar to offer high quality decking in American style. The American profiles are usually made of PE and have a wood share of 50%. The typical North American decking planks have a solid cross section, on the contrary to Europe where hollow profiles were produced from the beginning. PP used to dominate in European production, but this has changed, as the following figure shows. PVC and PE are mostly used in European decking production. The drivers behind this trend can be found in technical properties as well as in the price of the polymers.

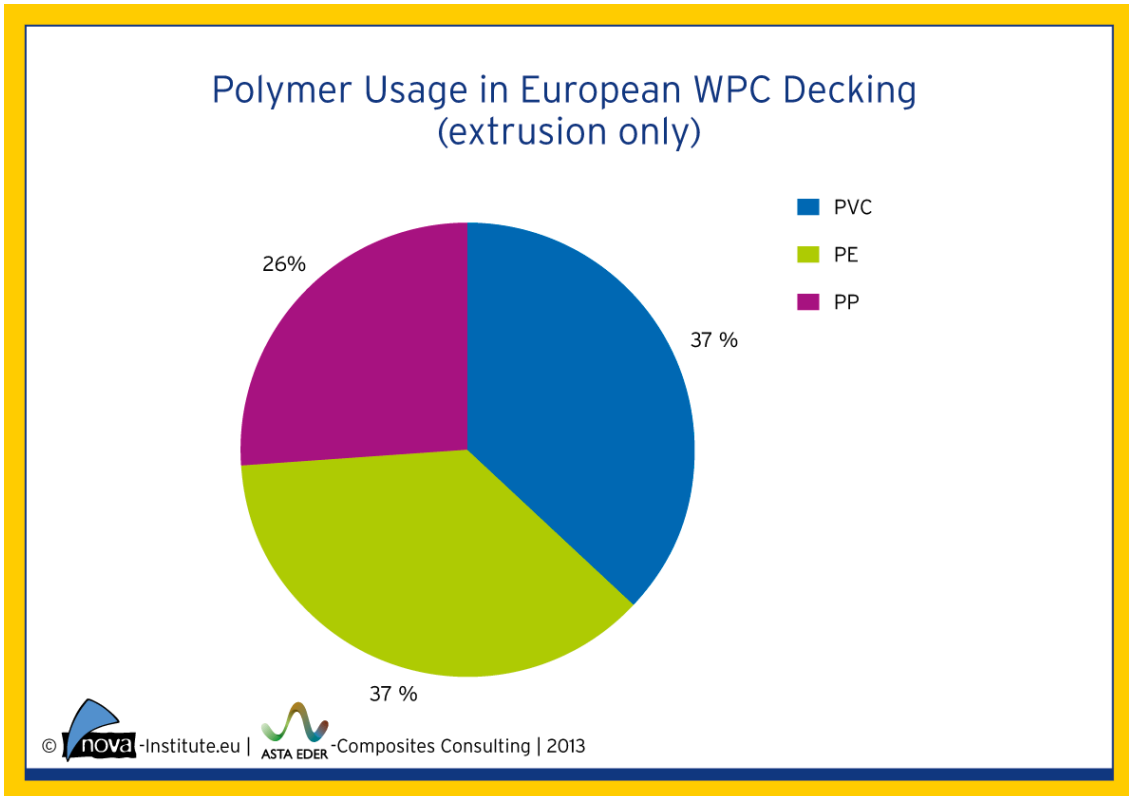


Figure 15: Polymers used by the European decking producers in 2012

The prices of decking boards (timber or WPC) varied in 2013 in the German speaking area between €40/m<sup>2</sup> and €170/m<sup>2</sup> depending on the material. These prices do not cover sub-structure or installation costs. Timber decks are found at both ends of the price range, high quality shows a slight rise in prices. The high demand of WPC decking and of thermally modified wood has led to a slight reduction of the price. The main drivers behind the increased demand are the high prices and the reduced quality of tropical wood. Reducing prices of WPC is likely to help market growth and this in turn is likely to permit producers to gain economies of scale, which has the potential of driving further market growth. Tropical wood and premium WPC as well as natural stone still range in the highest price level (Figure 16).

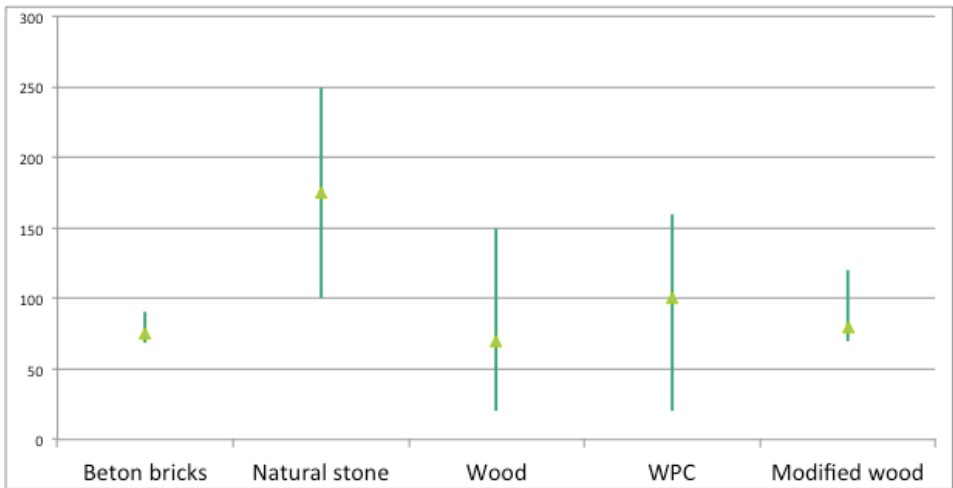


Figure 16: Terrace stone and decking price range Euro/m<sup>2</sup> incl. 20 % VAT

This study predicts strong growth in Europe area on the back of a slight recovery in construction and an increase in WPC's penetration in decking. We expect that the WPC decking market will grow at a rate of about 10% p.a. between 2013 and 2015. Beyond 2015 the market will continue to grow, but there will be less potential for substitution as the market gets more and more competitive. The long term potential for WPC is to achieve and maintain a market penetration of around 25% of the decking market as it did in North America. More would be unrealistic as Europeans has a strong affection to solid wood.

### *Global Overview*

Generally, there are four main reasons, which make the use of natural fibres and wood in plastics attractive: (1) They enhance specific properties e.g. stiffness and thermal behaviour (2) they reduce the price of the material (3) they heavily improve bio-based share and (4) they are better recyclable compared to glass fibres. Compared to talk and glass fibre, wood fibre offers a weight reduction for the composite, which can be of importance in transportation (Eder, Carus, 2013).

After more than 30 years of market development, the global Wood-plastic composite production reached 2.5 million tonnes of extruded material in 2012. Which means that with an average wood share of 52 % (extruded WPC in Europe 2012), 1.3 million tonnes of wood are used in WPC, which still is only a fragment of the total timber market. WPC is predominantly extruded worldwide to hollow or solid decking boards and is predominantly replacing tropical or pressure treated wood.

The oldest market can be found in North America where few big companies rule the market. The housing crises and the problems with product quality issues have led to a shake-out of several WPC producing companies. The number of companies has been sinking rapidly (only 58 companies was found in 2012) as only the successful ones could cope with the crises. Also aggregation could be noted e.g. Azek went together with Timber Tech. Today, only 5 big companies produce almost 90% of the market volume (Bizzarri, 2013). Conversion from wood to alternative decking materials, like WPC or cellular PVC or vinyl, is on-going but on a very low level (1 %).

In total, the share of alternative decking in the timber market rose from 2 % to 25 % in value between 1999 and 2010 (Bizzarri, 2013). Between 2007 and 2009 this conversion slowed down, but will grow again according to Bizzarri. The overall decking market in North America continues to grow with 6 % annually and the WPC production will grow with 4 % p.a. and will reach 1.3 million tonnes in 2015 if the market recovery in construction will continue. North American companies has been looking for market growth also world wide especially in Europe, were the demand for decking has been growing fast in the recent decade, as not only the WPC decking market was built but also the timber decking market grew from non-existing to a size of worldwide interest. On the contrary to North America the traditional material in European gardens until 2000 was natural stone. The development of the decking markets carries on now in several areas of the world, including China, India and Russia.

The growth of the North American decking demand will not be enough to hold the world leadership in production volume. It will be very likely that the Chinese production will overtake the North American by 2015 with 2.3 million tonnes p.a. (Figure 17). This has not only to do with almost 10 times more companies extruding there, although with lower productivity, but also with an governmental support in form from investments into WPC projects and in a demand generated by the huge Chinese domestic market e.g. in interior

fittings (Song, 2013). The Chinese government even has a plan to reach 5 million tonnes of WPC production in 2015

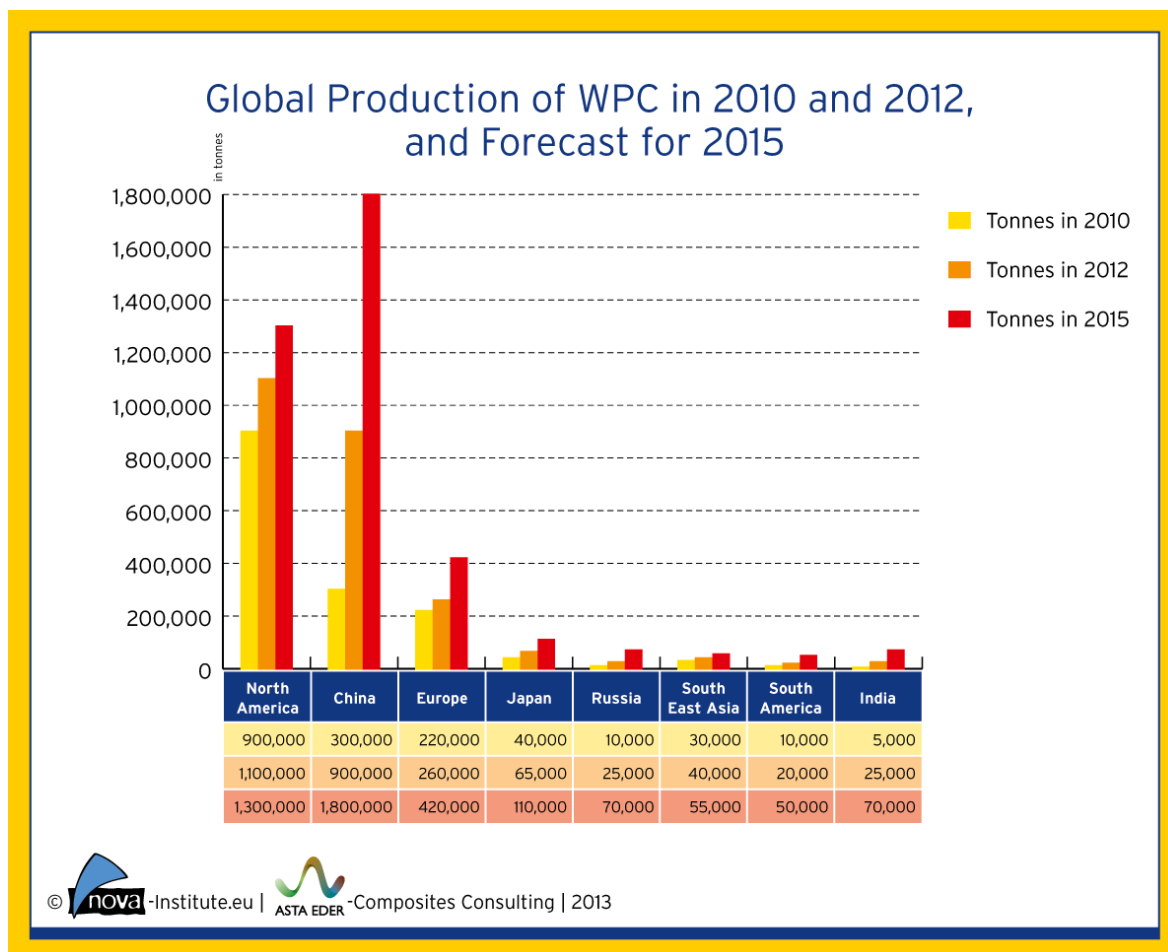


Figure 17: Global production of WPC 2010 – 2015

As has been mentioned already, today’s major production growth rates of WPC can be found in the Chinese WPC-extrusion (25 % p.a.). China’s WPC industry is the second largest in the world after North America and will be the biggest in 2015 with more than a 50 % market share according to the forecast (Table 7). In 2015, North America will be following China with a third of the global production. The overall European growth in WPC production lies at 10 % until 2015 and will lead to a 10 % share of the global market. After China, also Korean, South East Asian, Russian, South American and Indian WPC markets are emerging rapidly. India shows strong growth according to the vivid development of housing market in India (Table 7), the potential for WPC is gigantic if the quality issues and the distribution channels can be improved and the positive development of the total economy will continue.



Table 7: Global production and growth rates of WPC 2010 – 2015

	Tonnes in 2010	Tonnes in 2012	Number of producers in 2012	Average production per Company	Growth % p.a. 2010 - 2012	Tonnes in 2015	Growth % p.a. 2012 - 2015	Global share in 2015
North America	900 000	1100 000	56	19 643	11	1350 000	7	35%
China	300 000	900 000	422	2 133	73	1800 000	26	47%
Europe	220 000	260 000	62	4 194	9	350 000	10	9%
Japan	40 000	65 000	25	2 600	27	110 000	19	3%
Russia	10 000	20 000	30	667	41	40 000	26	1%
South East Asia	30 000	40 000	45	889	15	55 000	11	1%
South America	10 000	20 000	10	2 000	41	50 000	36	1%
India	5 000	25 000	21	1 190	124	70 000	41	2%
<b>Total</b>	<b>1515 000</b>	<b>2430 000</b>	<b>671</b>	<b>3 621</b>	<b>27</b>	<b>3825 000</b>	<b>16</b>	<b>100%</b>

The following Figure 18 shows the number of WPC producers in the world. The large number of Chinese producers, which amount to 60 % of the total number of 651 producers in 2012 is impressive, 80 % of them are Members of the two main WPC associations, one stemming from the plastic industry and the other from the wood industry. European and North American producers amount only to about 10% of the world’s total, but their productivity is much higher.

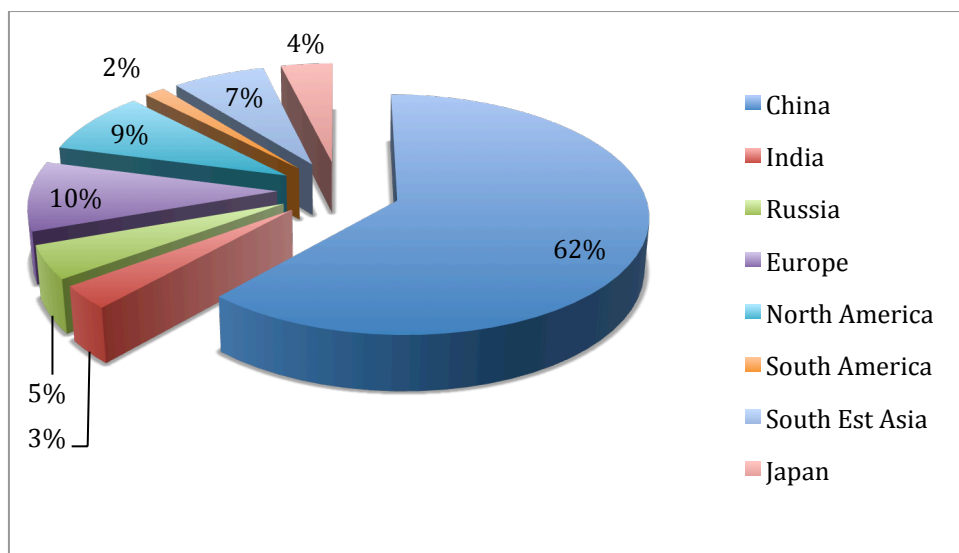


Figure 18: Global number of companies producing WPC, total = 651

### *Injection moulding with wood and natural fibres*

Is the “sleeping giant” of injection moulding with wood and natural fibres still asleep, since there are many obstacles to overcome? Most pessimistic actors believe there are presently too many barriers for injection moulding of bio-based composites. Still there are

a lot of signs in the market that the use of natural fibres, and especially of pulp and wood fibres has increased in injection moulding.

In Europe, 2012, 15,000 tonnes bio-based composites were injection moulded with an average fibre share of 42 %. 6% of the total production volume of bio-based composites in 2012 was injection moulded. 92 % of the polymers used was polypropylene, the share of biopolymer matrix amounted to 6 % and 2 % consisted of polyethylene.

The entire amount of companies that produced injection moulded products such as decking tiles, furniture, automotive interior parts, or consumer goods totalled 17 in 2012. 80 % of these companies used wood fibre, the other fibre sources applied were pulp, hemp, grass and cellulosic waste materials.

Some bottlenecks of the market for bio-based granules that are needed for injection moulding are shown with red lines between the market players in following Figure 19, which shows the value added chain of bio-based composites in Europe. One barrier is the price of the bio-based granules (anonymous compounder), which is far too high for the injection moulder. Another difficulty is obtaining the knowledge of the material, which is neither plastic nor wood, but a composite with new properties that have to be studied. The technical sales of bio-based granules are a challenge and can easily frustrate the trade personnel who is used to an easier job – which is selling standard polymers (Michels 2013). New process parameters like the necessity for additional drying of the compounds or applying reduced process temperatures (Korte 2013) are important barriers, too. The use of natural fibres also makes better tooling surfaces necessary than the ones used for standard polymers. Wood builds up moisture in the tool that includes acids, which can lead to corrosion of tooling. This can be handled with steel moulds that are more expensive as the aluminium ones. All changes in the standard polymer processes have to be mastered by processing personnel. The process control stands as one of the the hardest market obstacles for the use of bio-based composites in injection moulding.

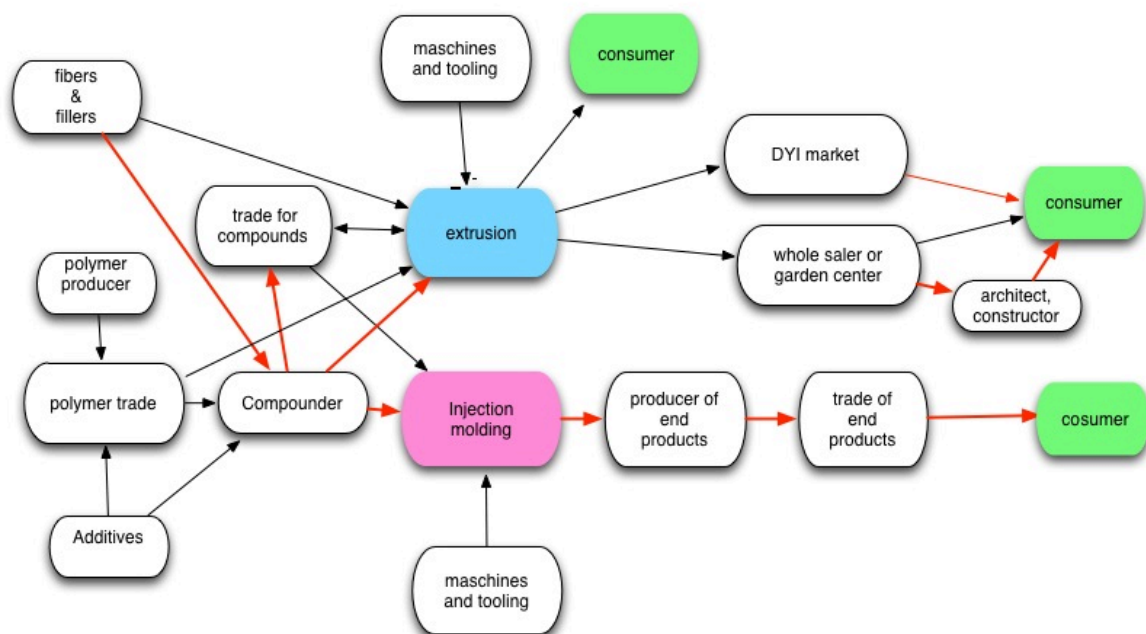


Figure 19: Value added chain of bio-based composites

Generally the market entry in WPC extrusion can be simple and easy during the first years with purchased know-how and material in form of granules from established WPC compounders. With an increasing knowledge of the process, the WPC extruder either goes for direct extrusion or makes their own compounds to be able reduce the production costs (Thometschek 2013). Some WPC producers sell directly to the customers, which brings monetary benefits, but also a knowledge about the customer need. This is normally not the case in injection moulding as injection moulders buy the compound depending on the end customers' wishes either from a trade house for compounds or from small very knowledgeable compounders. The trade house is not always the best possibility to get the assistance that is necessary to process the new material and it is not always so easy to find the right consulting and partners in this area.

Most WPC compounders are located in Germany. Identified prices of WPC and natural fibre granulates are diverging strongly, the figures provided by the manufactures are ranging between 1.0 €/kg and up at 4.0 €/kg. Beologic, the largest manufacturer of WPC granulates in Europe, offers prices from 1.10 to 1.60 €/kg. Soft wood is globally the first choice as a fibre source for WPC, although also rice husks play a role, especially in China. Wood prices differ from 0.2 – 0.4 €/kg, depending on quality and region. If wood is mixed with expensive biopolymers, the reduction of the composite price can be remarkable and the wood always enhances the bio-based share. With increasing plastic prices, WPC granulates for injection moulding are getting more and more attractive, and are increasingly found in the product range of the European granulate suppliers.

### 3 Cost price of different bio-based products in comparison with fossil alternatives

This section will investigate the most important price structures that determine the bio-based sector by looking first at the developments of prices of different feedstocks, then comparing costs of selected relevant bio-based materials with their fossil counterparts, and finally by discussing “Green Premium” prices paid for bio-based products.

#### 3.1 Price developments of raw materials

nova-Institute has been compiling price indices of different raw material groups since 1980. Figure 20 below shows a comparison of three different groups: The curve in red illustrates the average development of prices of a compilation of 18 commodities, metals and energy sources. In comparison to this, the blue curve shows the medium price developments of the four fossil energy sources natural gas, crude oil, heating oil and uranium. Finally, the black curve depicts the price developments of agricultural goods such as cotton, maize, soybeans, wheat and sugar.

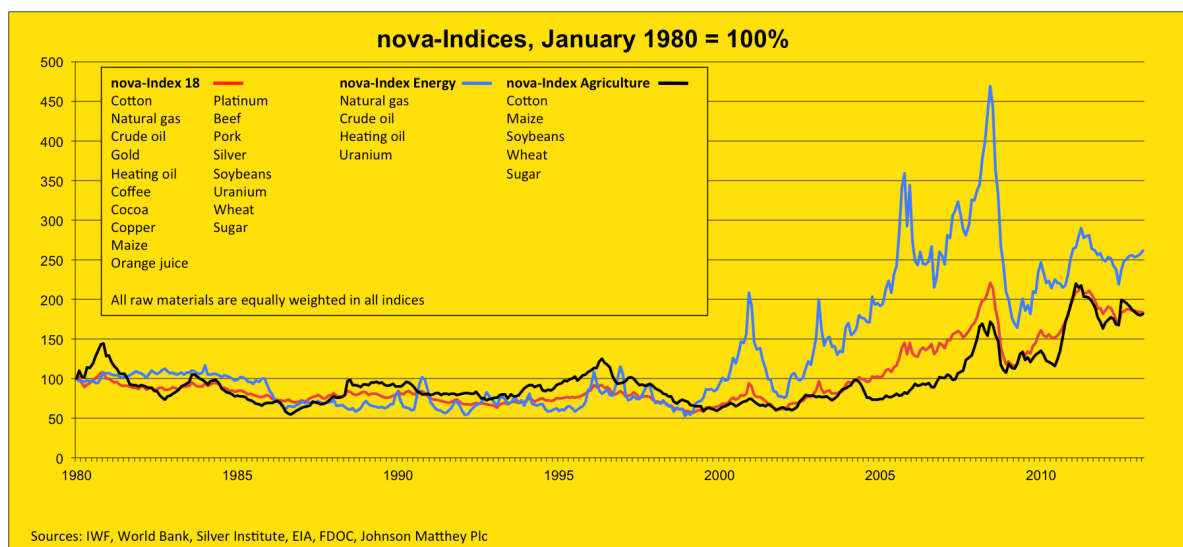


Figure 20: Price indices of different raw material groups since 1980

Several insights can be drawn from this depiction of price developments in the last 33 years. Firstly, it is very clear that all raw materials have been becoming more and more expensive since the beginning of the new millennium. The first peak in energy prices in 2001 (blue curve) was mainly caused by a shortage in natural gas in the US. The developments after this are very well known: The prices for fossil energy sources increased very steeply until 2008, “oil peak” was widely talked of, causing many developments in the direction of renewable alternatives for energy, but also for materials. In turn, the demand for agricultural resources, which are used for these new alternatives (next to solar and wind power, of course), increased, making them more expensive, too. Due to the economic crisis in 2008 and the resulting decrease in production and demand for raw materials, prices for all resources fell in 2008 and 2009. However, the trend turned around quite quickly and prices both for fossil as well for agricultural resources have been rising again since late 2009. Interestingly, the distance between the two price curves is now much smaller. For

some time in 2011, agricultural prices even increased at a much faster pace than fossil resources; however, they never became more expensive.

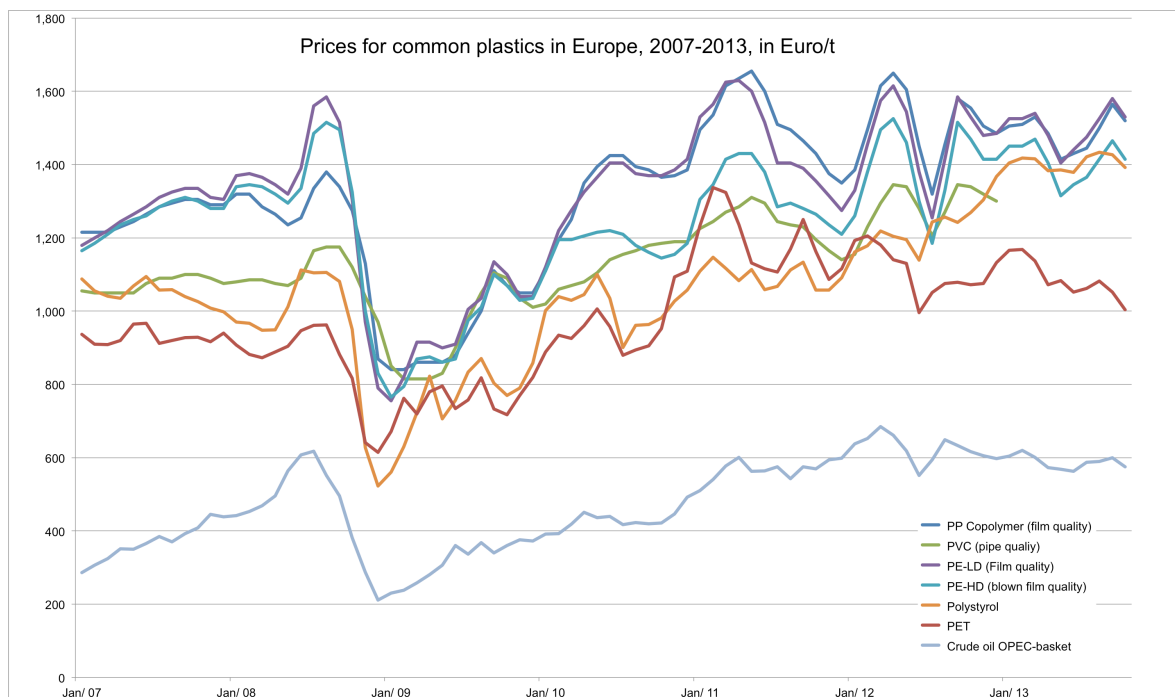
What does all of that mean for the future? Of course, nobody can predict any detailed development with 100 % accuracy. However, it seems clear that with a growing world population and increasing average consumption, the trend will continue to go towards rising feedstock prices. Raw materials are valuable and this will not change.

Against this backdrop, diversification of the raw materials base seems to be a good idea, may it be for energy or for material purposes. Many companies are actively pursuing this strategy. And even though there are quite a few voices that are now proclaiming a negative trend for bio-based solutions, since the oil prices are not developing as horrendously expensive as was predicted in the early 2000's, this speaks of a very short-sighted view. As can be seen from the curves, prices of fossil resources are still a lot higher than they used to be before 2000. Furthermore, the finality of fossil resources cannot be denied, even if the new fracking technologies let this fact fade more to the background in the recent debate. Again, this is a short-sighted approach, since this will change the picture for 10 to 20 years only. In the long term, the diversification of feedstocks is the only solution for any production. Furthermore, experts see opportunities for bio-based solutions in aromatics, which cannot be produced from natural gas, but have to be produced from oil, which is taking a backseat compared to gas production recently. In the future, there might therefore develop a market for aromatics from bio-based resources. (However, since there is no market yet, it was not included in the analysis above.)

It must be clear though, that biomass, which is a valuable feedstock, should be allocated to the most valuable applications in times of resource scarcity and rising prices. Current policy frameworks make it often more attractive to use biomass (respectively the land on which it is grown) for energy purposes, even though solar and wind power are viable alternatives for renewable energy provision. With a view to a growing global population and changing consumption patterns, this is not a sustainable solution and could mean that we cannot meet our demand for materials in the future. Therefore, bio-based materials should take priority in the allocation of biomass and land resources.

## **3.2 Price comparison of bio-based and fossil plastics**

It is relatively difficult to get clear information on prices of bio-based plastics, since there are no databases collecting this data. For fossil plastics, that is no problem, but for bio-based solutions we had to rely on information obtained from market players. In the following Figure 21 we compiled price information of the most common fossil-based plastics and crude oil from 2007 to 2013. As can be seen, the plastic prices correlate closely to the development of the oil price. Also here, we see a drop in prices after the crisis in 2008 and steady increases since 2009 / 2010.



**Figure 21: Prices for common polymers in Europe, 2007-2013.**  
(nova-Institute 2013, based on kiweb and icispricing 2013)

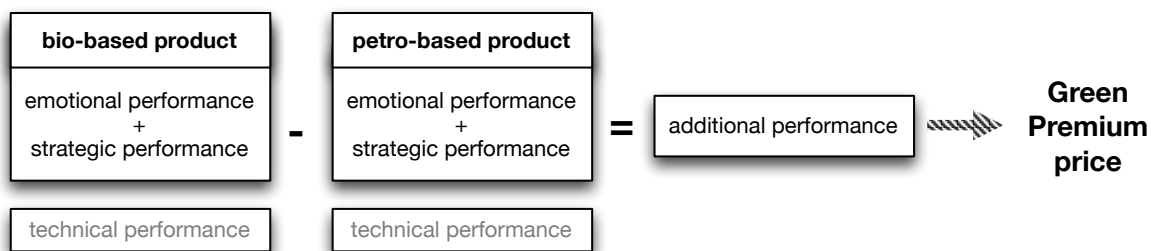
Compared to these price levels, the prices for bio-based polymers are in general higher. As mentioned above, it was not possible to obtain similar price curves, but market experts gave the following information during the last three years:

The prices for Polylactic Acid (PLA) range between 1.70 Euro and 2.20 Euro per kg, which would be slightly above the highest prices of the most expensive polymers in the curve above. For GMO-free PLA, the prices are much higher even; it is currently sold at 3.00 – 4.00 Euro per kg. PHB is sold at 4.00 to 6.00 Euro per kg. This shows that bio-based polymers are already successful on the market, even though they are still more expensive than their fossil alternatives. The reasons for this will be discussed below.

### 3.3 Green Premium within the value-added chain from bio-based chemicals to plastics

The Green Premium is basically understood as the extra price market actors are willing to pay for a product just for the fact that it is “green” or in our specific case “bio-based” (= derived from biomass).

For the first time, a comprehensive definition of Green Premium is proposed by nova-Institute: Green Premium is the extra price a market actor is willing to pay for the additional performance, and this is precisely the sum of additional emotional performance and strategic performance the buyer gets when choosing the bio-based alternative compared to the price for the (theoretical) conventional counterpart with the same technical performance.



**Figure 22: Definition of Green Premium price**

**Green Premium is defined as an additional price, depending on an additional emotional and strategic performance of the bio-based product, independently of the technical performance**

Based on this definition, the results of this paper clearly and unequivocally prove that Green Premium prices exist and are paid in value-chains of bio-based chemicals and plastics. A relevant group of market actors are already paying Green Premium prices throughout examined branches and in variable levels between 10 and 100 %.

The analysis shows that willingness of market actors to pay Green Premium prices is dependent on two factors:

- The additional emotional performance compared to the conventional counterpart
- The additional strategic performance compared to the conventional counterpart

The emotional performance is subjectively valued and mainly caused by the end consumer preference. The Green Premium effect is passed on through the value chain as consumer pull.

The value of a product's strategic performance that leads to Green Premium depends on the comprehensive market circumstances and framework of the company and the branch.

The results indicate that willingness to pay a Green Premium is always accompanied by strategic intentions, even though image and marketing aspects can be key decision factors. Other companies pay Green Premiums primarily for the strategic benefits. Strong drivers for strategic performance are (expected) public regulations to be met (e.g. non-degradable plastic bag bans in Italy or Asian countries), the opportunity to gain market potential or feedstock supply chain aspects.

This shows that willingness to pay a Green Premium prices has to be understood as an investment, on which companies expect a (delayed) return.

In practice, however, companies do not always succeed to enforce a Green Premium price on their customers, especially in long-term existing supply chains with established products. On the other hand, there are new investments for bio-based plastics (e.g. PE, PET, PP), which only have been developing upon demand, which in turn includes necessarily a confirmed willingness to pay Green Premium prices for intermediates over a longer period.

Results indicate that a relevant group of companies are paying a Green Premium price of around 10-20 % for bio-based intermediates, plastics and polymers. This can be found in a wide range of different applications and branches as this report shows.

Even much higher Green Premium prices are possible (50-100 % and beyond) under very specific market conditions and in a limited timeframe. This can be due to market scarcity (e.g. PE, PP), which in turn is compensated by additional image effects (exclusivity). The main reasons for achieving these high Green Premium levels are:

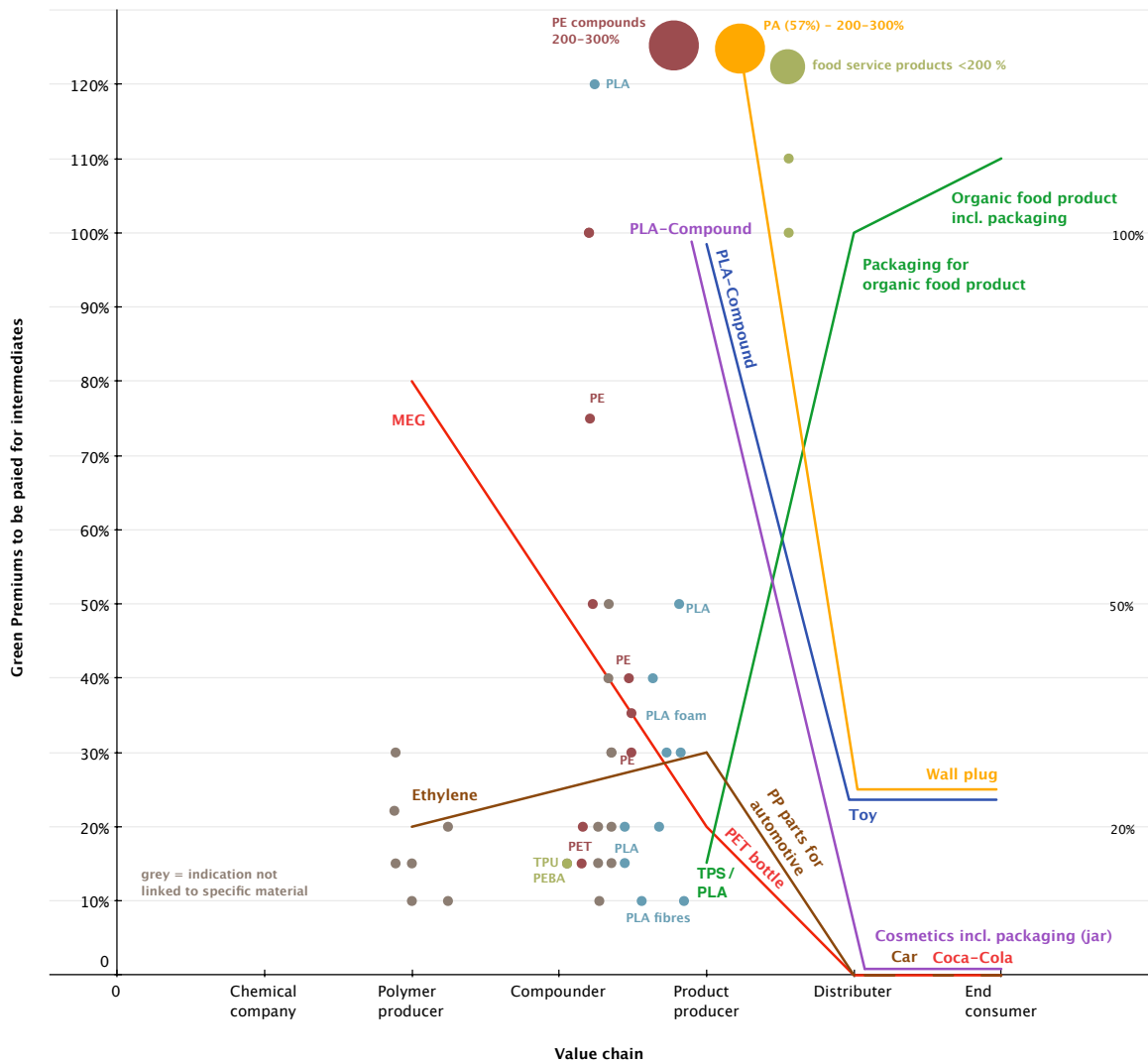
- Huge image benefit or significant strategic advantages for the producer (e.g. scarcity and exclusive access to a bio-based material).
- Material costs account for a small share of overall production costs.
- Niche markets are very sensitive to emotional performance.
- In some instances, Green Premium expenses can be fully and directly passed on along the value-added chain.

Based on the analysis of selected supply chains (Figure 23), empirical data shows that in most cases the Green Premium level decreases towards the end of the supply chain (end consumer). One reason is that the material costs share (including the Green Premium) of the total costs decreases along the value chain. Another reason is that without a confirmed Green Premium price for the intermediates, the whole value-chain would not have been implemented at all.

Additional product properties like non-GMO based polymers or the use of non-food crops can have an impact on the Green Premium level. This depends mainly on their emotional performance in individual cases. For non-GMO derived bio-based plastics it can be from 0% up to more than 100% depending mainly on specific markets and region. In regard to the emotional performance behind the mentioned product properties the respective Green Premium level is strongly dependent on end-consumer preferences.

The following figure shows the results of all expert interviews and surveys, undertaken and analysed in the context of the Green Premium study.





**Figure 23: Development of Green Premium prices along the value-added chain of different bio-based chemicals, plastics and end products.** Coloured lines represent one value-added chain, single dots represent single findings.

The Figure 23 shows identified Green Premium levels depending on where they are paid in the value chain; for example, the polymer producer buys a building block from the chemical company and might pay a Green Premium for it or the end consumer buys the final product and might pay a Green Premium to the distributor. Some identified Green Premium levels are coherent as they belong to the same value chain – they are represented by coloured lines. Other Green Premium levels are single findings (dots) and can therefore not be allocated to specific value chains. Some of the latter represent specific materials and are coloured (e.g. PLA in blue), others represent more general findings and are marked in grey (e.g. bio-based chemicals in general).

At first sight, the picture might seem complex as there is no overall trend identifiable. Next, it could catch one's eyes that the highest Green Premium levels are mainly located in the middle of the value chain, whereas one could think they would be at the end of the value chain (to be paid by the end consumer). The following analysis aims to provide explanations:

- **Falling colours lines:** The red, the violet, the blue and the yellow lines fall towards the end of the supply chain (as well as the brown lines which tends downward). In these cases the Green Premium levels decrease towards the end of the supply chain – relatively high Green Premiums are paid for (early) intermediate products, whereas the end consumer pays a much lower Green Premium or even no extra price at all. Reason is that intermediate products like polymers or bio-based plastics only account for a minor fraction of overall product costs with the effect that end product costs increase only slightly. At the same time, the end consumer is either willing to pay more – they honour the "Green touch" (emotional performance) as the wall plug example shows – or the product producer is willing to bear the extra costs themselves as they experience a strategic advantage (e.g. Coca Cola with an alternative raw material pillar, greening of the company image).
- **Ascending colours lines:** The green line ascends towards the end of the supply chain, which means that the highest Green Premium levels are paid by the end consumer. This situation can occur when a product is subject to very high emotional performance that would allow producers and distributors to pass on their extra-costs to the end-consumer. At the same time, overall product costs are relatively low for the end consumer. Bio-based packing for organic foods can serve as an example: small fraction of packaging costs, high emotional performance through "green packaging" fitting perfectly to the "green product".

**Unconnected points:** These points represent other empirically proved Green Premium levels in the market which could not be allocated to specific supply chains. The distribution indicates above-average Green Premium levels for compounds and polymers in comparison to chemicals or end products. However, it has to be considered that also most of the data was recorded in regard to polymers and compounds.

## 4 Position of the Netherlands on the global market

Based on the analysis of the global market developments of bio-based products in the previous chapters, this section will identify the position of the Netherlands in the European and world-wide bio-based economy. For this purpose, the existing structures of bio-based research and production in the Netherlands as well as weaknesses and strengths of the location will be examined. Finally, recommendations for a strengthening of the Dutch bioeconomy will be derived.

### 4.1 Existing structures of bio-based research and production

In the Netherlands, there are already several companies and institutions active with bio-based materials, covering a wide range of different products and also ranging from research to spin-offs and start-ups to established SMEs and big companies. The workshop held within this project was received with great interest from both industry players and consultants (see Annex I for information on the workshop).

We have compiled a list of companies manufacturing bio-based intermediates and products. The presentation is structured along the three market sections that were analysed in the first chapter in order to facilitate the assessment. Of course, due to the complexity of the bio-based materials sector, there also some companies which do not fit into this structure, so they will be mentioned separately. Also, this list does not claim to be exhaustive, but tries to sketch a picture as comprehensive as possible. At the end of each short description, the URL of each company can be found as well as the number of hits that appear for that company in the news portal [www.bio-based.eu/news](http://www.bio-based.eu/news). This news portal is another service of nova-Institute and is the biggest and most comprehensive collection of German and English press coverage of bio-based businesses. The number of hits therefore indicates the level of publicity in international news on bio-based topics of a company.

#### Chemicals, building blocks and others

**AkzoNobel** – large chemical corporation, world market leader in paints, coatings and functional polymers, several bio-based solutions part of the portfolio. Several years ago, the strong cellulose fibre business was sold to Lenzing (Austria), and it is developing very well. One example for bio-based activities of AkzoNobel is their cooperation with Solvay: AkzoNobel will progressively increase the use of Solvay's bio-based epichlorohydrin, or Epicerol®, which is already contained in many of the company's resins for its coatings products. The agreement underlines the commitment of both parties to play a key role in sustainable development and expand the use of renewable raw materials.

([www.akzonobel.com](http://www.akzonobel.com), **10 hits in news portal**)

**attero** – focus mostly on energy, but various utilization of biogenic waste, which illustrates an important diversification of feedstocks. Working on PHA, set up a pilot plant in November 2013. ([www.attero.nl](http://www.attero.nl), 0 hits in news portal)

**clea** – small, specialized company providing technology solutions for biotechnological processes. Also directly provide enzymes for these processes. (<http://cleatechnologies.com/>, 0 hits in newsportal)

**Corbion (formerly Purac)** – medium-sized company, world market leader in production of Lactic Acid (LA). They produce pure and high performance LA, which comes from GMO-free feedstocks. Truly global player with LA production in Spain and Thailand. Also active in research on succinic acid as another bio-based building block. ([www.corbion.com](http://www.corbion.com), **86 hits in news portal**)

**Cosun Biobased Products** – a small start-up company within the big Cosun Group. The group processes all kinds of biomass into different food products. The portfolio has also expanded to non-food bio-based products, so bio-based functional chemicals are developed and sold. Other sub-companies of the Cosun Group also valorize side-streams of biomass for the paper, oil or composite industries. ([www.cosun.com](http://www.cosun.com), 3 hits in news portal)

**Croda** – a large company producing additives and coatings for WPC and for bio-polymers. Important player in their section. ([www.croda.com](http://www.croda.com), **10 hits in news portal**)

**DSM** – large chemical corporation, very active in industrial biotechnology, various bio-based solutions in their portfolio, such as several types of bio-based polyamides and thermosets. Also involved in research on adipic acid. ([www.dsm.com](http://www.dsm.com), **79 hits in news portal**)

**forbo Flooring Systems** – a medium-sized, traditional company. Has produced linoleum flooring for a long time, world market leader. (<http://www.forbo-flooring.nl/>, 2 hits in news portal)

**Hortimare** – small company developing cultivation systems for open sea macro-algae, which is crucial for research and innovation in 3<sup>rd</sup> generation feedstocks. (<http://www.hortimare.com/>, 0 hits in news portal)

**Reverdia** – a big joint venture between DSM and the French company Roquette. World market leader in the production of succinic acid as a building block for bio-based chemicals. (<http://www.reverdia.com>, **9 hits in news portal**)

For all listed chemical companies, there is no information available about the volume of their bio-based chemical production in the Netherlands. With reference to German and European data, it can be expected that about 10% of the carbon feedstock of the chemical companies in the Netherlands is coming from biomass. The idea of the bio-based economy is that this share should rise, for example to 20% until 2030. But at the moment, there is no monitoring of an increase possible.

No Member State has collected data in this area. In Brussels the Joint Research Centre (JRC) is developing a methodology how to collect and monitor data on industrial material use of biomass in the Member States – nova-Institute is involved in this process. First data will be available end of 2014, earliest.

With companies such as AkzoNobel, Corbion, Croda, DSM and Reverdia the Netherlands are very well positioned in the sector of bio-based building-blocks, chemicals and coating / paints – in Europe and world-wide: The hits in the news portal show that they are also internationally very active. Corbion, DSM and Reverdia are part of international cooperations, connected with French, German, Italian and US companies.

Research and development takes mainly place in the Netherlands (in cooperation with leading Dutch research institutes), but investments in new processing lines often go to Asia and America, and in Europa most of the new bio-based investment take place in France and Italy.

## Polymers and plastics

**Avantium** – a young, medium-sized company, spin-off from Royal Dutch Shell, developing innovative bio-based monomers (FDCA) by a chemocatalytic conversion of bio-feedstock and subsequently innovative new bio-based polymers (and other applications for the FDCA building blocks). They use well-known as well as completely new technologies to produce Polyethylene Furanoate (PEF), and have managed to engage with big partners in order to further the development and the commercialization of their innovative products, e.g. Coca Cola. In 2013, no commercial production has taken place. By 2020 there could be an investment in a big PEF plant (400,000 t/year) – but this could also take place outside the Netherlands. They illustrate the successful scaling-up from research and are also active in more research projects now, for example in order to win bio-based polymers from algae. ([www.avantium.com](http://www.avantium.com), **30 hits in news portal**)

**DSM** – also a large polymer and plastic corporation, very active in industrial biotechnology, various bio-based solutions in their portfolio, such as several types of bio-based polyamides and thermosets. There is no information available about the total bio-based production of DSM. A few thousand tonnes could be a realistic estimation. ([www.dsm.com](http://www.dsm.com), **79 hits in news portal**)

**Rodenburg Biopolymers** – a medium-sized company producing starch polymers from potato waste for packaging etc. Good illustration of the connection between the agro-industry and bio-based materials in the Netherlands. In the meantime, they extended their production line with non-starch based bio-plastic compounds and with masterbatches. The current production capacity is about 40,000 tonnes per year. This will expand due to the new activities. Total capacity is expected to increase to 65,000 tonnes per year in 2020. ([www.biopolymers.nl](http://www.biopolymers.nl), **12 hits in news portal**)

**Synbra** – a small company, producing GMO-free PLA from LA from Corbion. With this very special product, they have managed to enter a high-priced market. Focus on foams for packaging and insulation etc., but also targeting other market segments. Production capacity was 5,000 tonnes in 2013, there are plans to expand to 75,000 tonnes by 2020. ([www.synbratechnology.nl](http://www.synbratechnology.nl), **14 hits in news portal**)

**Transmare Compounding** – a medium-sized company active in WPC production and compounding of bio-based plastics. They are one of the leading compounders in Europe and complete the process chain of bio-based polymers in the Netherlands (from LA production, to PLA, to compounds). Bio-based production is unknown and is estimated to be less than 500 tonnes / year. ([www.transmare.nl](http://www.transmare.nl), 3 hits in news portal)

**Veolia Water** – a water company has experimented in Groningen with PHA from waste water. The latest status is unknown. ([www.veoliawater.nl](http://www.veoliawater.nl), 7 hits in news portal)

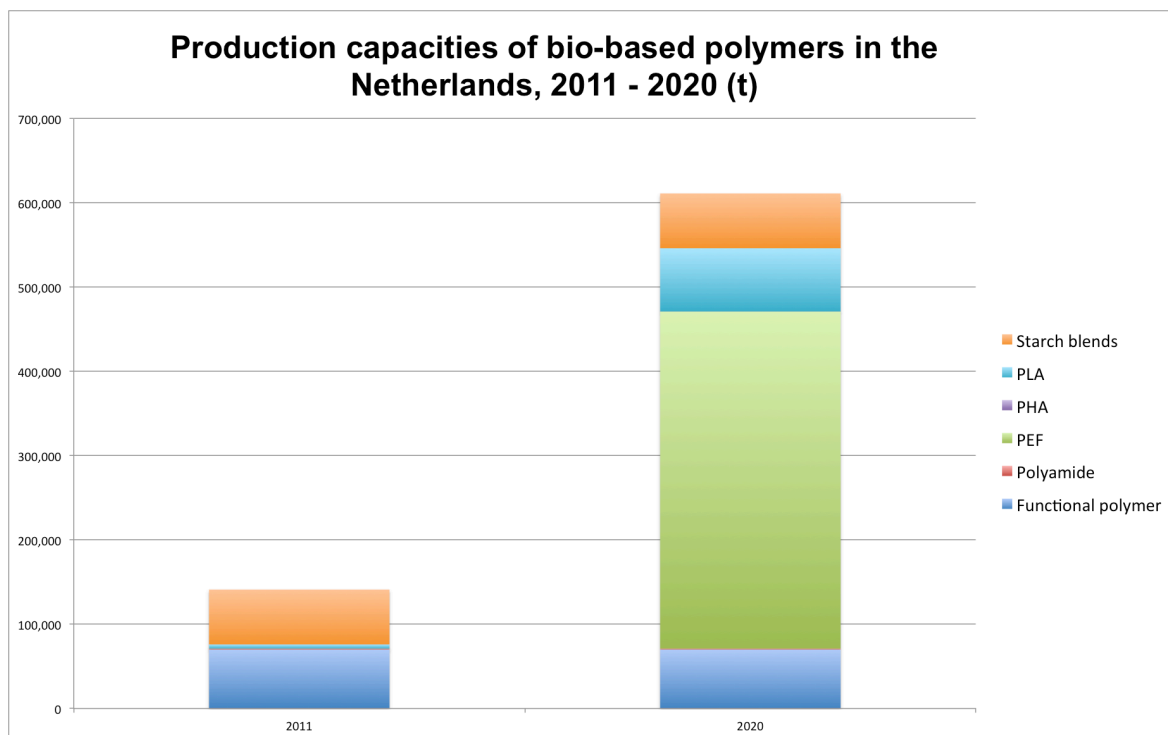


Figure 24: Production capacities of bio-based polymers in the Netherlands, 2011 and 2020 (nova-Institute 2013)

Also in plastics and polymers, the position of the Netherlands is very good, the Netherlands surely belong to the leading European countries together with Germany, France and Italy. The production capacity (including functional polymers, which are produced by the Canadian company EcoSynthetix and are therefore not included in the company list) is today more than 100,000 tonnes – the production in 2013 might be lower, not all capacities in starch blends could be utilized. The further development is depending mainly on Avantium, whether they will invest and produce in the Netherlands or not.

The share of biopolymer production in the total Dutch polymer production might be about 1 – 2%, as it is in Europe and also world-wide. Exact shares could not be calculated, because the total polymer production volume of the Netherlands could not be found. The Netherlands are a net exporter of plastics and articles thereof, exports were 7.4 Mio. tonnes and imports 4 Mio. tonnes in 2012.

Our rough estimation shows that companies in the Netherlands produce about 10% of all bio-based polymers in the European Union. That seems to be not that different from the Dutch share of all plastics.

Avantium and Synbra are surely forerunners in the field of new bio-based polymers. DSM is offering very specific high value polymers and Rodenburg is a forerunner in using agricultural by-products. Transmare is one of the very few European compounders, developing ready-to-use plastic granulates from bio-based polymers and also fibres.

### Natural fibre reinforced composites

**Enkev** – medium-sized company, producing a wide variety of products for the furniture, automotive or insulation market from natural fibres. No data on production volumes available. (www.enkev.com, 0 hits in news portal)

**GreenGran** – a small company, spin-off from WUR, producing the technically best natural fibre reinforced granulates in the world. However, they encountered problems with scaling up the production, so the location in the Netherlands was recently closed. Operations continue from China, though. No data on production volumes available. (www.greengran.com, **9 hits in news portal**)

**Hempflax** – a medium-sized company, after French producers the biggest hemp business in Europe. Their hemp cultivation is now expanding, taking place also in Bulgaria and Romania. The company is one of the leading developers of Hemp processing technology and also of new applications. Producing up to 5,000 tonnes / year of hemp fibres for technical applications such as insulation and automotive parts. (www.hempflax.com, **31 hits in news portal**)

**NPSP** – a small, specialized company producing very high-quality natural fibre reinforced composites. One of the very few companies using resin transfer moulding (RTM) technology and their applications go to high-priced niche markets. No data on production volumes available. (www.npsp.nl, **7 hits in news portal**).

With GreenGran, HempFlax and NPSP the Netherlands have very specific companies in the field of biocomposites, which is a unique situation in Europe. The main reason might be the strong research activities in this field in WUR in the past. Scaling up is still a problem for these companies – also depending on their specific technologies and products.

The total production of fibres and also of biocomposites will be lower than 5,000 t/year. For HempFlax we see the possibility of an expansion by 2020, but mainly outside the Netherlands, where soil and labour are more economical.

## **WPC**

**Aviplast** – small company, hosting several patents of WPC technology, but no own production. (www.aviplast.nl (currently not working), 0 hits in news portal)

**Deltawood** – medium-sized company; their main product applications are: cladding, decking, sheet piling, fencing and railing. Active in the continuous reinforcement of the composites. Continued development of “Simply Housing” and custom profiles ongoing. Currently no production, only technology development. (www.deltawood.nl, 1 hit in news portal)

**Green Gran** – see part on NFC above.

**Tech-Wood** – small company, produced wood-plastic composites for construction (cladding, decking, sheet piling, fencing and railing) between 2000 and 2007. Since then, Tech-Wood has stopped production and has only been licencing the technology also in cooperation with Deltawood, which licences WPC emergency housing. (www.tech-wood.com, 2 hits in news portal)

**Transmare** – see part on polymers above, produce also granulates of bamboo fibre reinforced bio-based plastics.

In the first phase of WPC production in Europe between 2002 and 2009, the Netherlands were well positioned with the company Tech-Wood, which possessed a production capaci-

ty of 10.000 tonnes and was thus one of the biggest manufacturers in Europe. Meanwhile, the picture has changed significantly: Tech-Wood is focusing solely on technology development and licensing, the production has shifted completely to the U.S. and Asia. Several other companies develop technologies and act as licensors, but the real production is taking place only in small companies and amounts to less than 500 tonnes per year.

The Netherlands seems to be a good location for technology development, innovation and niche production, but not for mass manufacturing of WPC. This is perhaps also true for other materials.

The situation is very different in Belgium, where at least two big manufacturers of WPC granulates, deckings and other products are located. The share of Belgian WPC production in the EU is remarkably high.

Since this situation concerns only very few relevant companies, however, the big differences between the Netherlands and Belgium could result from singular decisions, management errors etc. and do not allow any basic conclusions about the framework conditions for investments and production in the Netherlands.



## 4.2 Strengths and weaknesses of the Netherlands as a location for the development of a bioeconomy

The following table proves again the top position of the Netherlands in the bio-based economy in Europe and also the world. The table is based on hits in the news portal, i.e. how often the country was mentioned in bio-based news in English and German. In Europe, the Netherlands takes the third position after Germany and France and before Italy. Considering the size of the Netherlands this is an excellent position.

Also on world level, only USA, China, Japan and Canada generate more hits in the news portal.

<b>bio-based news - how often was the country mentioned?</b>		
<b>(out of 12,877 news from 1998 - 2014; survey done 2014-01-10)</b>		
<b>Country</b>	<b>in English news</b>	<b>in German news</b>
<b>Europe</b>		
Germany	538	2,883
France	232	338
The Netherlands	177	218
Italy	146	232
Austria	145	650
Finland	92	92
Belgium	90	147
Spain	84	118
Sweden	69	186
Denmark	64	68
Switzerland	60	303
Poland	43	146
<b>World</b>		
USA	2,181	3,899
China	497	507
Brazil	295	261
Japan	270	247
Canada	262	141
Malaysia	155	137
Thailand	121	82

Furthermore, within the framework of the project for NL Agency, several interviews were conducted with Dutch experts on bio-based economy in order to assess their opinion on the Netherlands as a location for the development of bio-based materials and chemicals. The experts who gave input were: Jan Ravenstijn, one of the leading international experts on bio-based polymers, Elsbeth Roelofs (and her team), consultants from TNO, as well as

Christiaan Bolck and Hariette Bos, both researchers from Wageningen University. All four of them are renowned experts in their field and have been working for many years in the Dutch bioeconomy. They named several strengths and weaknesses of the Netherlands, which are summarized in the following:

***Strengths of Dutch economy for bio-based materials and chemicals:***

Several of the interviewees named the presence of a large and state-of-the-art chemical industry infrastructure in the Netherlands as one of the key advantages. In the vision paper of the VNCI, the search for alternative feedstocks is mentioned as an element of further developing the chemical industry in the Netherlands. However, some experts also pointed at the circumstance that often, existing industries have vested interests in keeping up the status quo and are not very willing for new developments, which also mean new competitors. One expert correspondingly criticized the VNCI report for not expressing real interest in true innovation, but focusing more on making existing things better. So, an established chemical industry can present advantages, but the motivation for changing to bio-based feedstocks needs to be strong in order to create change.

On the other hand, there are already a multitude of bio-based industries in the Netherlands (agriculture, food industry, horticulture, paper industry) that are looking for new outlets in order to diversify and develop. Here, new bio-based materials and chemicals are very attractive options, since the value added created from biomass is much higher for these products than for energy products. In the Netherlands, there is great potential for a stronger cooperation between agricultural, plastic and chemical industries, which are all already existing and for which also the know-how is there. Competencies that were not associated before (like chemistry and agriculture) now need to become strongly associated to enhance innovative power and subsequent economical activity.

The knowledge base is further improved by excellent university programmes and top-notch research, which was stressed by all experts.

Furthermore, the Netherlands is a trading hub and thus possesses an excellent logistics network via sea, air, road, rail and rivers, which provides access to all European markets. Especially for biorefineries, this could be a decisive advantage, since they need to be built where biomass is easily available, which is often next to ports. Especially the port of Rotterdam as the most important trading port of Europe therefore gives a crucial asset to the Dutch bioeconomy.

Access to aquaculture might be an important advantage for the development of 3<sup>rd</sup> generation feedstocks, too.

But also “soft” factors have come up during discussions. It was mentioned that in the Netherlands, there is a culture of cooperation between government, industry, research institutions, NGOs and the public. This also leads to a very strong awareness of the necessity of improving the public’s knowledge and perception of the bio-based economy. The qualitative study “My 2030s”, which was carried out at four different locations in the Netherlands, for example found that consumers do not have a clear definition of the term “bio-based” in mind, but mostly associate good things with it. Even though the study also found that many consumers do not really know much about what is going on in bio-based production and development, the existence of such a study shows that the Netherlands is one of the pioneers in this field. Also the willingness of government and public authorities to consult with expert knowledge from different sources signals openness for development, change and innovation.

### *Weaknesses of Dutch economy for bio-based materials and chemicals:*

Although the experts identified many strong points, they also saw room for improvement in some aspects of the Dutch bioeconomy. One more general remark was that still, the political awareness of opportunities for prosperous future developments is inadequate, or that politicians are not willing to make tough choices, which results in far too low support levels for several areas, including the bioeconomy.

Strong criticism was expressed about the unlevelled playing field between bio-based materials and bio-energy as well as between bio-based and fossil materials. More concretely, bio-based energy receives a lot of subsidies, whereas materials do not receive funding. For more explanation on this and approaches to solving this, see Chapter 5 on policy.

As a potential weak point, the lack of available feedstock was mentioned. However, this seems to be somewhat controversial, since other experts expressed the view that biomass is available in sufficient amounts in the Netherlands, especially sugar and starch plants. According to them, the true problems lie with the investment conditions.

Concerning incentives for bio-based businesses, all experts agreed that the conditions need to be improved in order to make the Netherlands more attractive for setting up new bio-based productions. The example of Corbion illustrates very well that innovative and successful bio-based companies often do not choose the Netherlands as a production location, due to much better conditions offered in other countries, e.g. Thailand. Also other Asian or North and South American countries offer stronger incentives for these companies. Experts explained this lack of incentives with the strong mind-set that is convinced of a free market, which is predominant in the Netherlands. Therefore, subsidies for industries are frowned upon (and would – at current legislation – often lead to legal disputes over distortion of competition). All experts, however, stressed how important it would be to support especially small and medium enterprises in their innovative ventures – by providing more financial incentives and capital, space for experimentation and by reducing bureaucracy. This was seen as the crucial weakness of the Netherlands, which fits well into the overall structures in Europe and which results in more and more investments taking place elsewhere in the world.

Summary on the position of the Dutch Bio-based Economy in Europe and world-wide

## SWOT ANALYSIS: Bio-based industry in NL

	Helpful to achieving the objective	Harmful to achieving the objective
Internal origin <small>attributes of the biomass</small>	<ul style="list-style-type: none"> <li>➤ Biomass: Important by-products from farming and greenhouses (tomatoes, tulips ...), manure for biogas. Easy access to world wide biomass stream via Port of Rotterdam. Strong and resource efficient sugar beet industry, forerunner in algae use (macro and micro).</li> <li>➤ Strong research institutes, strong chemical and polymer/ plastic industry infrastructure, several global players in bio-based economy.</li> <li>➤ Great potential for a stronger cooperation between agricultural, plastic and chemical industries, which are all already existing and for which also the know-how is there.</li> </ul> <p style="text-align: right; color: #4f81bd; font-weight: bold;">Strengths</p>	<ul style="list-style-type: none"> <li>➤ Total biomass production per capita is lower than in other countries (due to population density).</li> <li>➤ Investment framework for chemical and polymer industry is a weak point: Labour costs and access to biomass to reasonable prices, and also low support compared to biofuels and bioenergy.</li> <li>➤ Established chemical and polymer companies have vested interests in keeping up the status quo and are not very willing for new developments, limited motivation to switch to bio-based.</li> <li>➤ The political awareness of opportunities for prosperous future developments is still inadequate.</li> </ul> <p style="text-align: right; color: #4f81bd; font-weight: bold;">Weaknesses</p>
External origin <small>attributes of the environment</small>	<ul style="list-style-type: none"> <li>➤ Most of the European countries are less active in the field of bio-based chemicals and polymers, focusing totally on biofuels and bioenergy.</li> <li>➤ The framework for bio-based economy is starting to change in Brussels, there is the political will to reform the whole framework to support the chemical and the polymer sector. The Netherlands could be one of the most profiteers of this development (which should be supported by the Dutch government).</li> <li>➤ Investments in biofuels are decreasing, because especially the mandate for food crop-based fuels are mostly reached. Bio-based chemicals and polymers could be the next focus.</li> </ul> <p style="text-align: right; color: #4f81bd; font-weight: bold;">Opportunities</p>	<ul style="list-style-type: none"> <li>➤ Image of sugar beet as a food crop is a hurdle to use sugar beet as a raw material for chemical industry.</li> <li>➤ Very good investment framework for bio-based chemicals and polymers in Asia (Thailand, Malaysia) and America (US, Canada, Brazil) which attracts investors.</li> <li>➤ No incentives for commercial production of bio-based chemicals and polymers by the Brussels framework.</li> <li>➤ No level playing field - strong incentives for biofuels and bioenergy in Europe only (in contrast to Asia and America)</li> </ul> <p style="text-align: right; color: #4f81bd; font-weight: bold;">Threats</p>

## 5 Policies influencing the development of bio-based markets

The development of an innovative industrial sector is influenced by many different factors. Among others, the political framework conditions in which such a sector is built play an important role. This chapter will look at how different parts of the world handle the development of the biomaterials sector politically.

It should be noted that the motivations for supporting the bio-based economy vary strongly from region to region. In the US, the driver for bio-based products and plastics are resource security and agricultural market policy, while in Japan there is a strong drive towards products with a green image. In Europe, resource utilisation, GHG emissions, recyclability and compostability are important drivers in developing supporting policies. Industrial development is an important driver in South East Asia, Brazil and China.

In contrast to biofuels, there are currently no strong, comprehensive policy frameworks in place to support bio-based materials (such as mandatory targets, tax incentives, etc.), and as a result, these products suffer from a lack of raw material supply (at reasonable costs), investment security or also consumer confidence.

In the market report, there is a long chapter elaborating on political frameworks on a global scale. For the purpose of this study, the different political measures applied in various countries and regions will be summarized, based on the market report and on the OECD report on policies for bioplastics (OECD 2013). It should be noted that general recommendations as given by the Lead Market Initiative, roadmaps or strategies concerning the bioeconomy are not considered in this part. The chapter will only look at specific, concrete measures that are designated to create a market pull. For this reason, also R&D policies are not considered. Since often the step from research to commercialization is the crucial and most difficult one for innovative materials, it can be misleading to applaud a comprehensive R&D scheme while forgetting that the scaling-up is often failing. Of course, this does not mean that research is not important – but for the purpose of this market analysis, we will truly focus on market measures.

In a second step, the measures that exist for biomaterials will be compared to the support system in place for biofuels and bioenergy and then some approaches for Europe and the Netherlands will be discussed that may promote a level playing field for the bioeconomy.

**Table 8: Overview of policy measures implemented to promote the market developments of bio-based materials**

<b>Country \ Measure</b>	<b>Investment incentives</b>	<b>Mandates</b>	<b>Public procurement</b>	<b>Bans / Fees for conventional plastics</b>
<b>Thailand</b>	x			
<b>Japan</b>		(x) <sup>1</sup>		
<b>South Korea</b>	x		x	x
<b>Malaysia</b>	x			
<b>China</b>	x			
<b>Brazil</b>	x			
<b>US</b>	x		x	x <sup>2</sup>
<b>Canada</b>				x
<b>Netherlands</b>			(x) <sup>3</sup>	
<b>Germany</b>			(x)	
<b>Italy</b>			(x)	x
<b>Denmark</b>			(x)	x
<b>Bulgaria</b>				
<b>Israel</b>				x
<b>United Arab Emirates</b>				x

This overview does not claim to be exhaustive, but it summarizes the concrete policy measures that have been implemented worldwide to create a market pull for bio-based materials. As a comparison, the following table gives an overview of which political schemes have been put in place in order to support energy won from renewable resources (including electricity, heat and transportation fuels) in high-income countries (REN21 2013).

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<sup>1</sup> Non-binding target.

<sup>2</sup> In some States.

<sup>3</sup> Green public procurement (GPP) is a policy instrument in an EU framework, implemented to some extent by most member states. Most of them do not cover bio-based products, however, since the environmental advantageousness is controversial. So this is not a support instrument for bio-based materials per se, but can be if designed in the according way.

Table 9: Renewable energy support policies in high-income countries (REN21 2013).

TABLE 3. RENEWABLE ENERGY SUPPORT POLICIES

	REGULATORY POLICIES AND TARGETS							FISCAL INCENTIVES				PUBLIC FINANCING	
	Renewable energy targets	Feed-in tariff premium payment	Electric utility quota obligation/RPS	Net metering	Biofuels obligation/mandate	Heat obligation/mandate	Tradable REC	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO <sub>2</sub> , VAT, or other taxes	Energy production payment	Public investment, loans, or grants	Public competitive bidding/tendering
<ul style="list-style-type: none"> <li>● indicates national level policy</li> <li>○ indicates state/provincial level policy</li> </ul>													
<b>HIGH INCOME COUNTRIES \$\$\$\$</b>													
Australia	●	○			○		●	●			●		
Austria	●	●			●		●	●			●		
Barbados	●			●							●		
Belgium	●		○	○	●			●			●	●	
Canada	○	○	○	○	●			●		●	●	●	
Croatia	●	●						●			●		
Cyprus	●	●			●			●			●		
Czech Republic	●	●			●		●	●		●	●		
Denmark	●	●		●	●		●	●		●	●	●	
Estonia	●	●			●					●	●		
Finland	●	●			●		●	●		●	●		
France	●	●			●		●	●	●	●	●	●	
Germany	●	●			●	●		●	●	●	●	●	
Greece	●	●			●			●	●	●	●		
Hungary	●	●			●			●		●	●		
Ireland	●	●			●	○	●				●	●	
Israel	●	●	●		●					●	●	●	
Italy	●	●	●	●	●	●		●	●	●	●	●	
Japan	●	●	●	●	●		●	●	●		●		
Luxembourg	●	●			●			●		●			
Malta	●	●		●				●		●			
Netherlands	●	●		●	●		●	●		●	●		
New Zealand	●												
Norway	●				●		●	●		●	●		
Oman								●		●	●	●	
Poland	●		●		●		●	●		●	●	●	
Portugal	●	●	●	●	●	●		●	●	●	●	●	
Singapore		●		●							●	●	
Slovakia	●	●						●		●			
Slovenia	●	●						●				●	
South Korea	●		●	●	●		●	●	●		●		
Spain <sup>1</sup>	●	●		●	●	●		●	●	●	●		
Sweden	●		●		●		●	●	●	●	●		
Switzerland	●	●						●		●			
Trinidad and Tobago	●							●	●				
United Arab Emirates	○		○			○				○	○	○	
United Kingdom	●	●	●		●	●	●	●		●	●	●	
United States		○	○	○	●	○	○	●	●	●	●	●	

When comparing tables 8 and 9, it becomes clear that the level of support is overwhelmingly tipped in favour of the energy compared to materials. Not just the quantity of implemented support measures is important in this regard – however, it should be noted that this table is only one third of the original table from the source. Even in middle, lower and lowest income countries, a multitude of policy measures has been introduced to promote renewable energies (REN21 2013), but those parts of the table have been left out for the purpose of readability of this study. And of course, not all measures promoting renewable energies create an unlevelled playing field for bio-based industries, since a lot of them target solar and wind power. However, whenever bioenergy is covered by such measures –

which it is often – then other sectors depending on biomass are also concerned due to competition for feedstocks.

Furthermore, the quality of the measures should be taken into account when a comparison of markets is made. For energy, we see binding targets, guaranteed premium prices, tax incentives and other very strong instruments in place, which have a significant impact on market development. For materials, these strong measures are rare. In the Asian region and in the U.S., tax incentives for establishing a bio-based business are given on a significant scale. But everything else – except for the bioplastics mandate in Thailand – consists of quite weak instruments. Binding targets for industries are frowned upon in most countries and regions, since they are not easy to define and handle, create market distortions and are thus also vulnerable to legal claims due to unfair competition. This is a major difference to the strictly regulated energy market.

Green public procurement might become a more powerful instrument; however, the approach in Europe is far less pragmatic than for instance the American one. So far, there is no European standard on what is a bio-based product (the Technical Committee TC411 of the European standardisation body CEN is currently working on this circumstance), whereas the Biopreferred Program of the United States government has introduced a clear standard of what is a bio-based product. Products can undergo certification, and as soon as they have the certificate, they are placed on a product list, which is secure for public authorities to use for their procurement. In contrast, public authorities in EU member states need to follow quite complicated guidelines on what is environmentally advantageous before they can justify decisions for their procurement. So far, this leads to a fragmented landscape of green public procurement and not to a significant boost of innovative industries.

### *A level playing field for bio-based materials*

In order to design policies that promote the bioeconomy it is important to understand the dynamic of the whole sector. Analyses by the nova-Institute have identified more than 50 individual barriers hindering the industrial material use of biomass from developing (the report is forthcoming in early 2014 and will be published by the Germany Federal Environmental Agency), even though a lot of work is done in research and innovation. One crucial reason is the lack of available risk capital and the resulting difficulties of scaling up from lab level. But the most important problem faced by the material use of biomass is the distorted competition towards petrochemical products as well as energy won from biomass. The following Figure 25 explains this dynamic as a whole. It shows:

#### *Right side: Bio-energy/biofuels and material use competing for biomass*

Material use and bio-energy compete for the biomass not used for food and feed. As a result of the comprehensive support system in place for bio-energy and biofuels – originating from the Renewable Energy Directive (RED) – prices for biomass and land have increased immensely. This makes it hard for the material use to get access to biomass, because there is no support system which could compensate for this development. A difficult and “un-fair” (as in: resulting from a market distortion) competitive situation.

#### *Left side: Petro-chemical products competing with bio-based products*

The petro-chemical industry and the bio-based industry face each other in open competition, only dictated by the laws of the market. Without any accompanying regulations, new bio-based industries are supposed to flourish and compete with mass products that have been established and optimised over decades by the petro-chemical industry. This is further exacerbated by the high prices for biomass, resulting from the support for the energetic



use, which are not counteracted by a tax on fossil carbon sources as raw materials for the chemical industry – a difficult and almost non-manageable competitive situation.

*Upper side: Fossil energy competing with bio-energy/biofuels*

Due to the comprehensive support system for the energetic use of biomass, originating from the RED and its national implementations such as EEG, biofuels quotas and tax reductions, an artificial competitive situation compared to fossil energy sources has been created over the years. Furthermore, the latter are subject to a substantial energy tax – extremely favourable competitive conditions for bio-energy and biofuels, artificially created competitiveness.

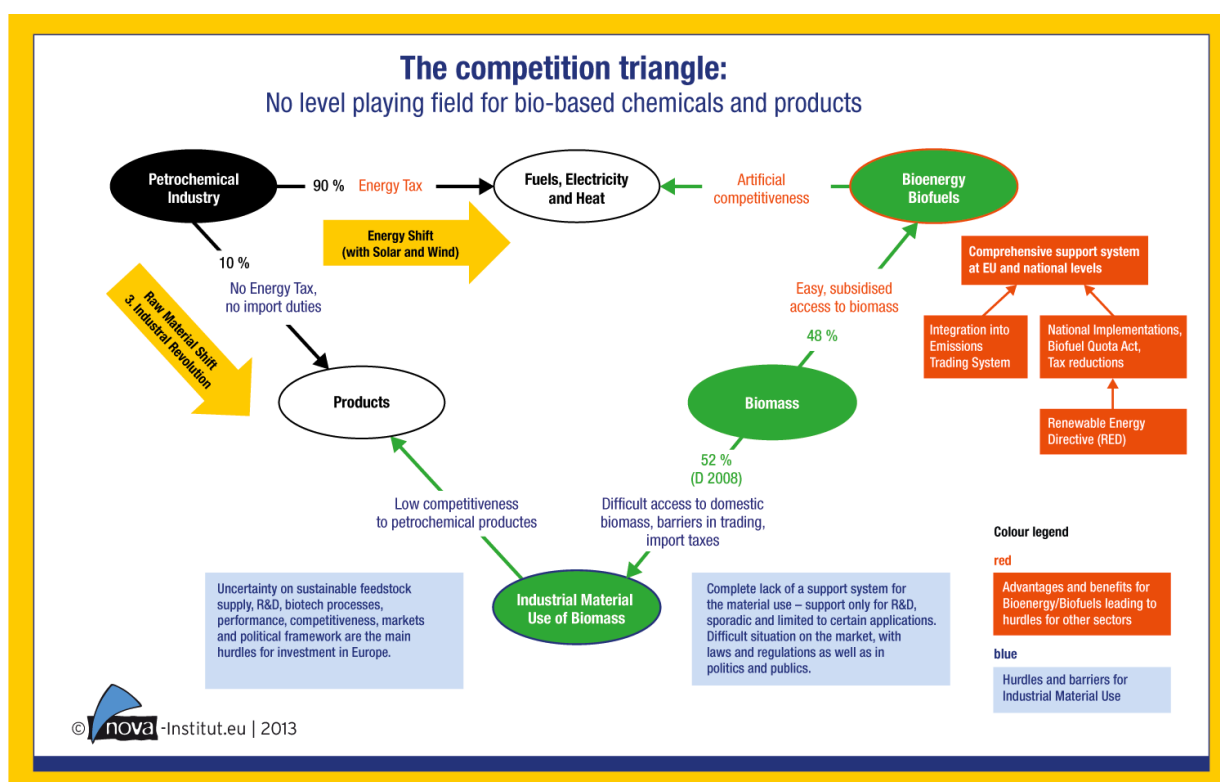


Figure 25: The competition triangle between industrial material use of biomass, bioenergy and the petrochemical industry

The current support landscape leads to a systematic allocation of biomass to the energy uses, at the disadvantage of bio-based materials and chemicals. Due to the subsidies, the energy uses can simply afford to pay higher prices for agricultural land, which makes it difficult for some bio-based sectors to secure a sufficient supply of feedstocks. Several industries have started to complain about these circumstances and to fight for a fairer allocation of biomass (e.g. the wood-working industries, pine chemicals, oleochemistry and mulching industries).

**Conclusion**

In order to support the relatively young sector of bio-based chemicals and plastics, several aspects need to be kept in mind. The different developments in Asia or the Americas compared to Europe should make policy makers aware of the fact that supporting demonstration and pilot plants, bans, tax incentives and public procurement can be powerful instruments to boost the bioeconomy. European countries need to revise their frameworks in

order to catch up on the trend and to secure investments in Europe. An secondly, it is crucial to create a level playing field for bio-based materials compared to bioenergy as well as to the petro-chemical alternatives. In order to create a fairer competition for biomass between materials and energy, it would be thinkable to modify the support systems for bioenergy in a way so that types of biomass, which can be used for high-value material applications, are not made overly attractive to be allocated to energetic uses. A general cap on bioenergy shares within the renewable quota could be a viable tool, as well. Alternatively, an interesting solution could be making the support systems for bioenergy available for industrial material uses, too. nova-Institute is working on a comprehensive proposal to reform the renewable energy support framework in the EU, which will be published in the first half of 2014 and will consider each of these aspects in detail.

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