Innovative Biomaterials in Europe – Status and outlook

Bioplastics, NFRP & WPC and other innovative wood materials

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nova-Institut

NACHWACHSENDE ROHSTOFFE
RENEWABLE RAW MATERIALS

DIVISION

Renewable Resources Market Research & Economics

nova institute
for ecology and innovation

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Our mission

We use and create expert knowledge to facilitate a shift in energy and raw materials through the use of renewable resources.

- Market research and economic analysis
- Feasibility studies
- Project development
- Network and project management
- Industrial and political consulting
- Collaboration with national and international organisations
- Knowledge transfer, events and congresses

Our scope of vision ranges from regional to global ...
... and from today until the day after tomorrow.

The departments of nova-Institut

NACHWACHSENDE ROHSTOFFE
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Economics & Resource Management

- Bioenergy
- Material Use
- Biotechnology

Photo: Claas

Photo: InfraServ

Biomaterials

- Bioplastics
- Natural Fibre Reinforced Plastics
- Wood-Plastic Composites (WPC)
- Timber products

Photo: Daimler AG

Photo: JELU WERK Josef Ehrler GmbH & Co. KG

Communication

- IT and Print
- Congress and event management

Photo: J. Fischer

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Department

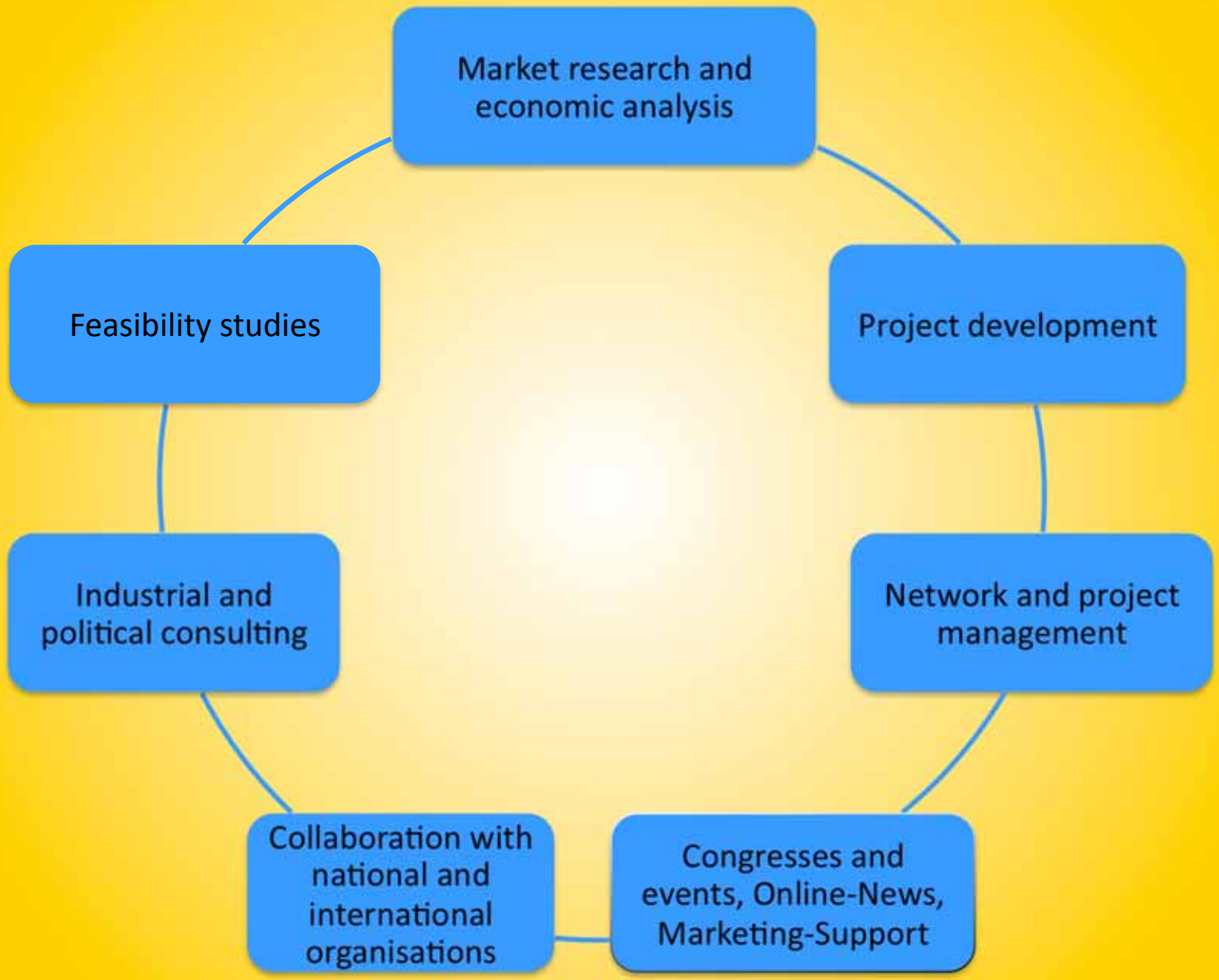
Biomaterials


Photo: Daimler AG


Photo: JELU WERK Josef Ehrler GmbH & Co. KG

Main fields of activity:
Bioplastics, natural fibre reinforced plastics, wood-plastic composites (WPC) and timber products

- **Analysis of global and local markets for biomaterials**
- **Assessment of technical and economic feasibility as well as environmental impact**
- **Marketing support**
- **Product development with the help of our network of technical experts**
- **Innovation and knowledge transfer**


Market research and economic analysis
Project development
Network and project management
Congresses and events, Online-News, Marketing-Support
Collaboration with national and international organisations
Industrial and political consulting
Feasibility studies

Definition

Innovative Biomaterials

Biomaterials are materials which are based either completely or to relevant proportion on agricultural raw materials or timber. Typical agricultural raw materials – in this context also called „ Renewable Resources“– are for example starch, sugar, vegetable oils and cellulose (timber, natural fibres, straw) and special bio-molecules such as lignin or natural rubber. The proportion of these agricultural raw materials in the material should be at least 20 %.

In contrast to traditional biomaterials such as particle boards or plywood, “novel” or “innovative” biomaterials are often converted by modern plastic processing procedures such as extrusion, injection moulding, deep drawing or blown film.

Source: nova-Institut 2008

Why biomaterials (= biobased materials)?

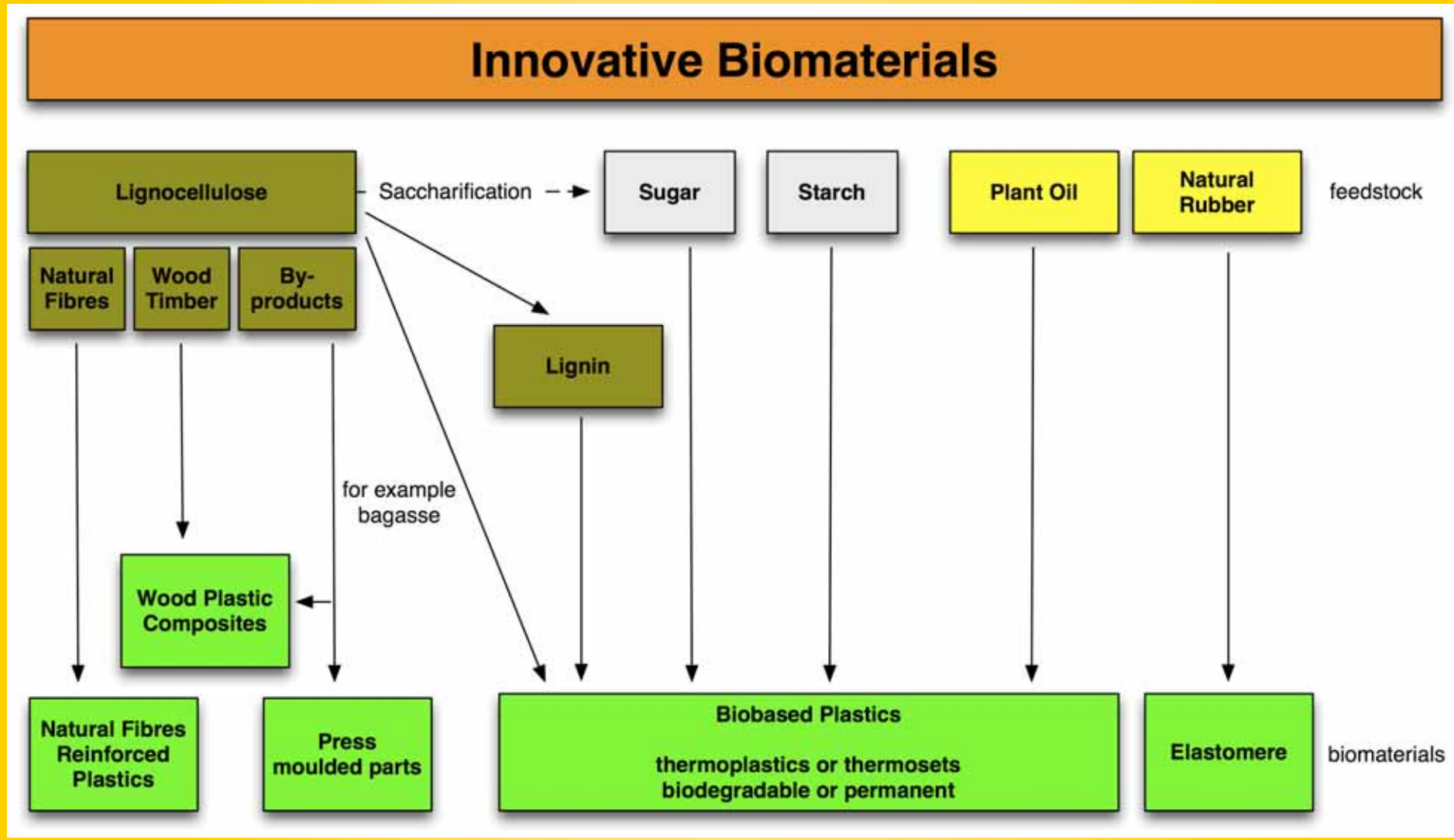
Green materials – environmental advantages (CO_2 saving) and positive marketing image

Interesting material properties – for example biodegradable, but also other specific properties like lightweigth, special haptics …

Feedstock diversification – less depending on mineral oil and less depending on oil price

Saving finite resources – by using renewable feedstock

Rural development – more added value and jobs in the processing line


Innovative Biomaterials
Lignocellulose
Saccharification
Sugar
Starch
Plant Oil
Natural Rubber
feedstock
Natural Fibres
Wood Timber
By-products
Lignin
for example bagasse
Wood Plastic Composites
Natural Fibres Reinforced Plastics
Press moulded parts
Biobased Plastics
thermoplastics or thermosets
biodegradable or permanent
Elastomere
biomaterials

nova-indices

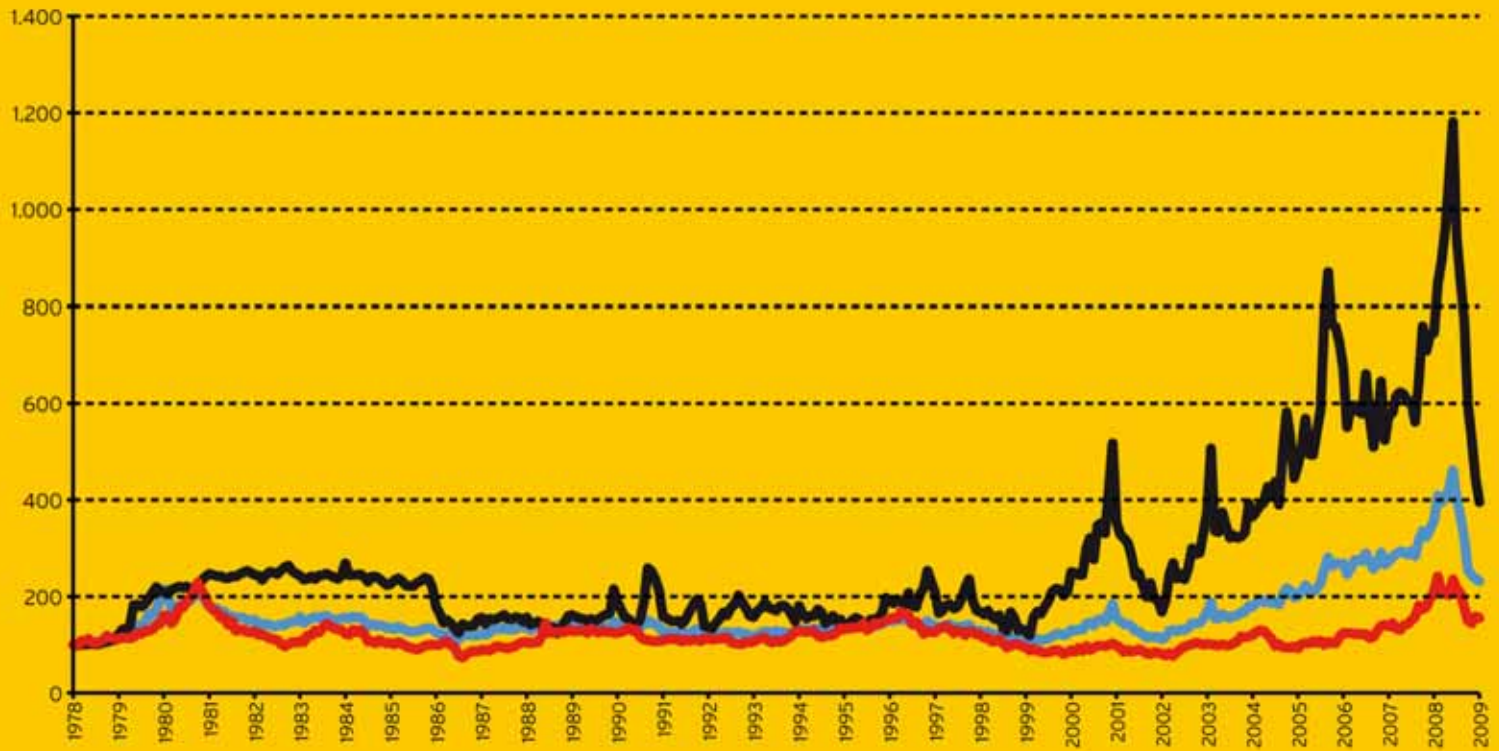
January 1978 = 100

The commodities are equally balanced among all indices

nova-Index 17
corn
soy beans
wheat
live cattle
lean hogs
gold
silver
copper
cocoa
coffee
sugar
cotton
orange juice
platinium
crude oil
heating oil
petroleum gas

nova-Index energy
crude oil
heating oil
petroleum gas

nova-Index agriculture
corn
soy beans
wheat
sugar
cotton

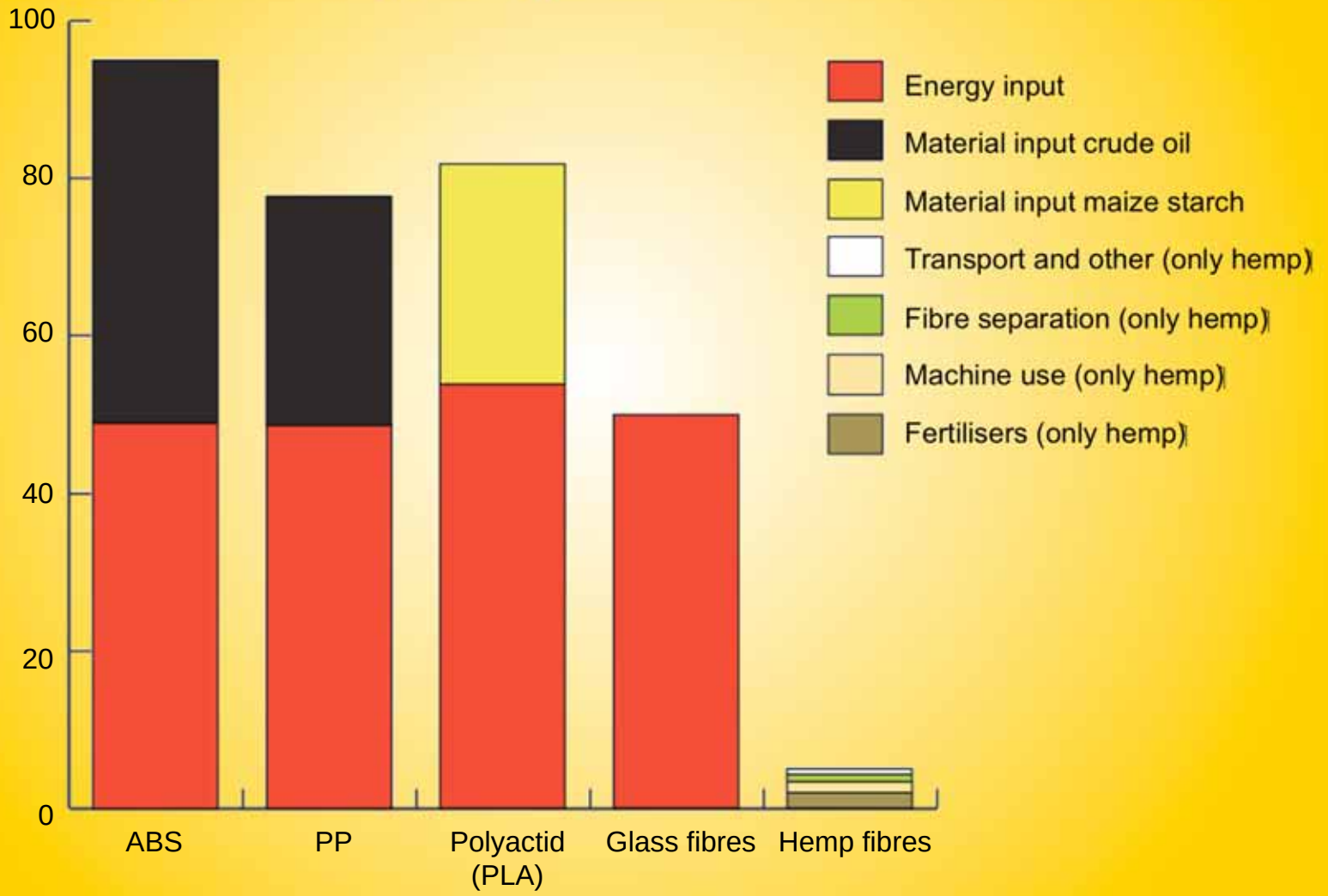


available at: www.nova-institut.de/nr

Sources: CRB, World Bank

Environmental advantages

Cumulated energy demand (MJ/kg)



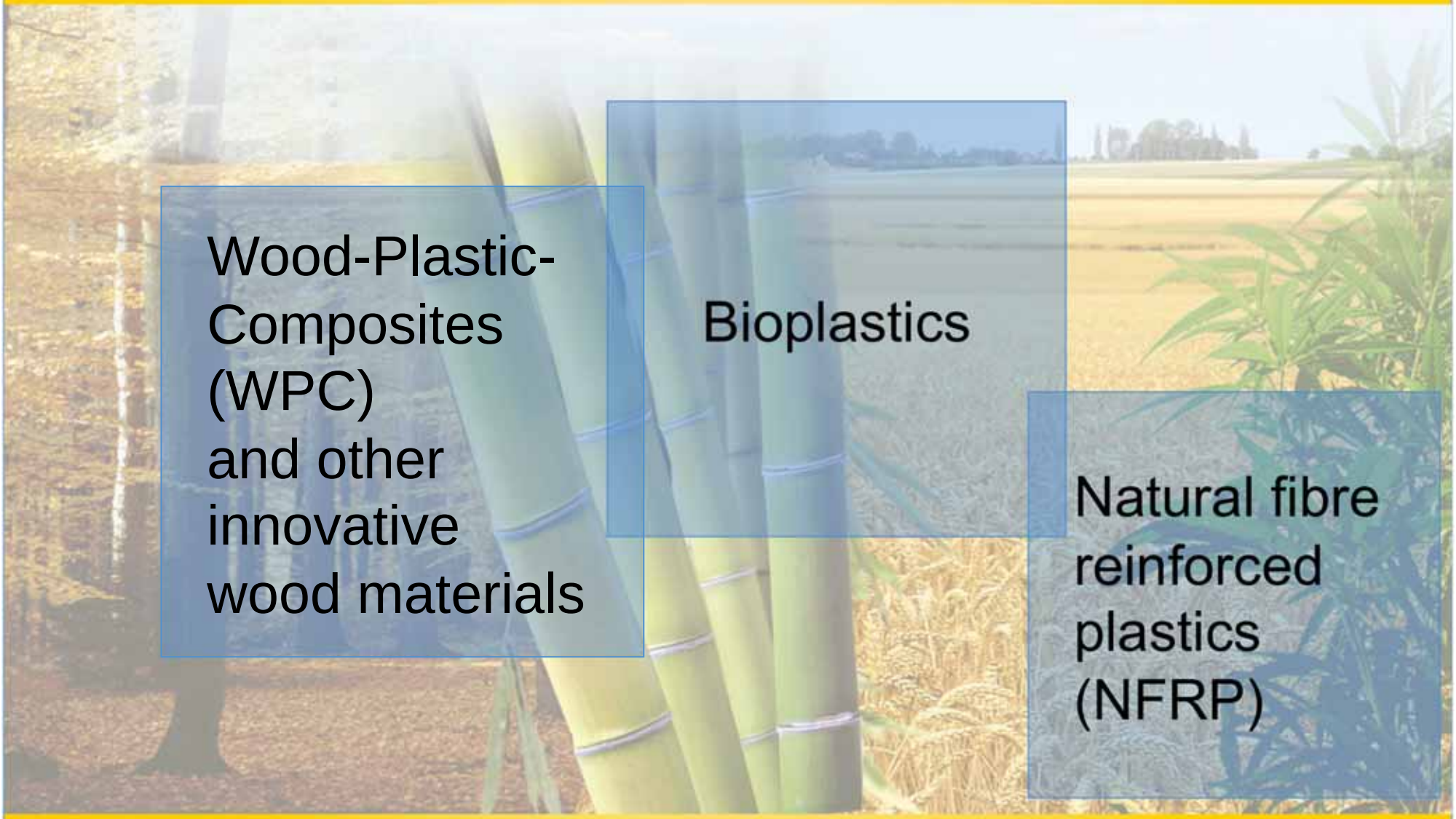
Source: nova-Institut u.a. 2007

Summary: Biomaterials in the EU

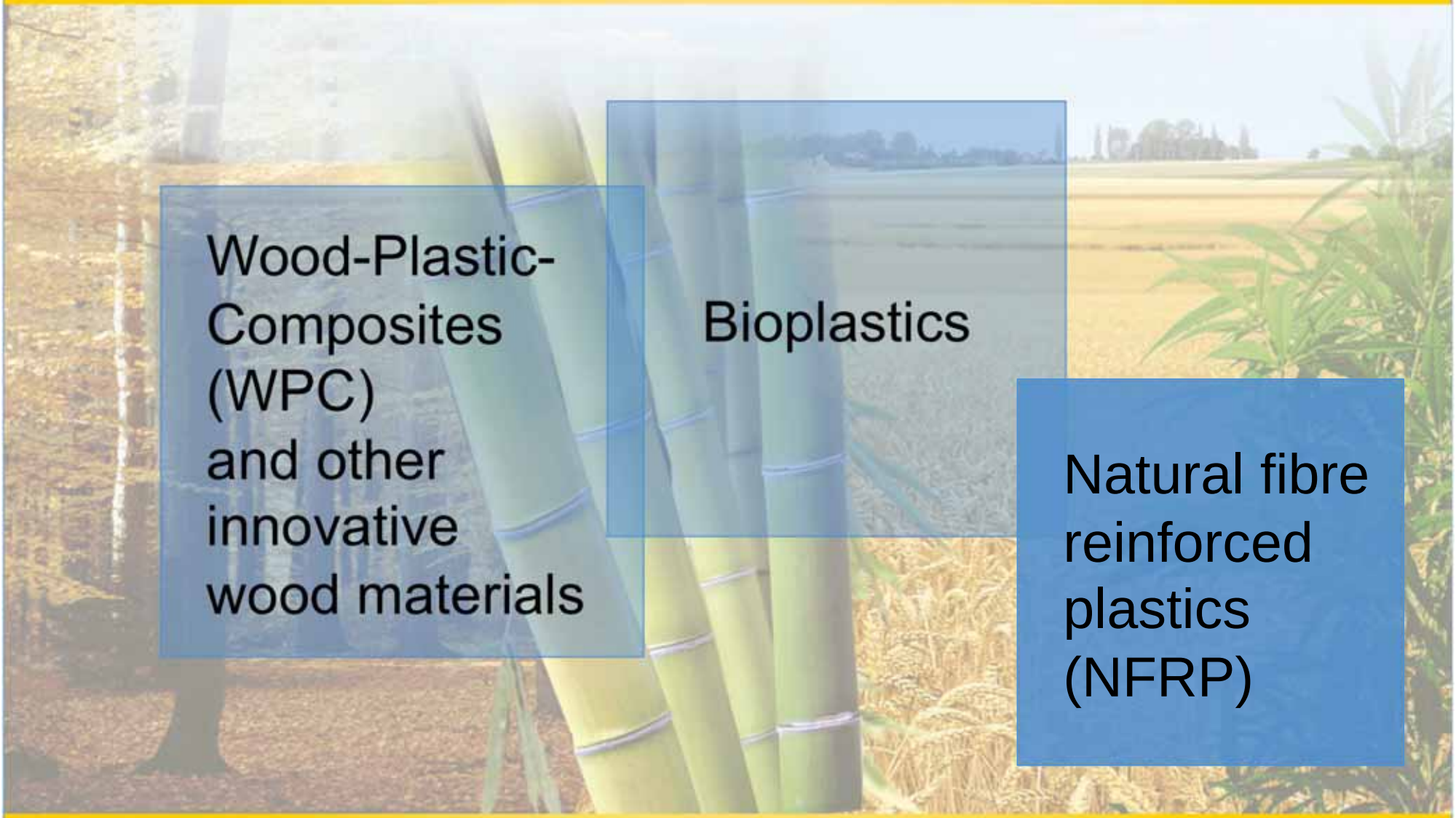
New Biomaterials – Technique	Quantities – Region
Biodegradable bioplastics (mostly packaging)	60,000 – 70,000 t (Western Europe 2007)
Bioplastics in permanent applications	30,000 – 40,000 t (Germany 2007)
NF compression moulding in the automotive industry	29,000 t (Germany 2005)
Wood fibre compression moulding in the automotive industry	40,000 t (Germany 2005)
Cotton fibre compression moulding (lorries)	79,000 t (Germany 2003)
WPC injection moulding and extrusion (construction, furniture, automobiles)	80,000 – 105,000 t (EU 2006)
NF injection moulding and extrusion	3,000 – 4,000 t (EU 2006)
Total biomaterials	More than 350,000 t in the EU

Source: nova-Institut 2004, 2006, 2007

Innovative Biomaterials



NFRP


Wood-Plastic-Composites (WPC) and other innovative wood materials
Bioplastics
Natural fibre reinforced plastics (NFRP)

The most important markets for NFRP

Automobiles – Construction and Furniture – Industrial and Consumer Products

Source: Daimler 2007, Wilkhahn 2008, Aveda 2007

Automobiles Example: NFRP and WPC in Daimler automobiles

A-Class, weight: 24 kg – 26 units

C-Class, weight: 17 kg – approx. 20 units

E-Class, weight: 32 kg – 50 units

S-Class,

weight: 43 kg (+73 % compared to S-Class – 32 units

Source: Daimler 2007, FiberGran 2007, nova-Institut 2008

Automobiles

Example: NFRP in Lotus (study) and BMW automobiles

BMW 5 Series

Fibre

Non-woven fleece

Naked door

Finished door

Source: Lotus 2008, BMW 2008, nova-Institut 2008

Automobiles

NFRP press moulding

Total amount: approx. 30,000 t/a
NFRP composites in Germany

Fibre use: approx. 19,000 t/a,
mostly flax (approx. 65%)

Approx. 98% press flow- and compression moulding in the automotive industry, 2% injection moulding

Approx. 1/3 press flow-moulding with thermoset bonding agents

Stable market with a new potential

Interior door paneling
Hemp-polypropylene

Interior Audi R8

Source: Audi 2008, nova-Institut 2008

In detail: NFRP press moulding

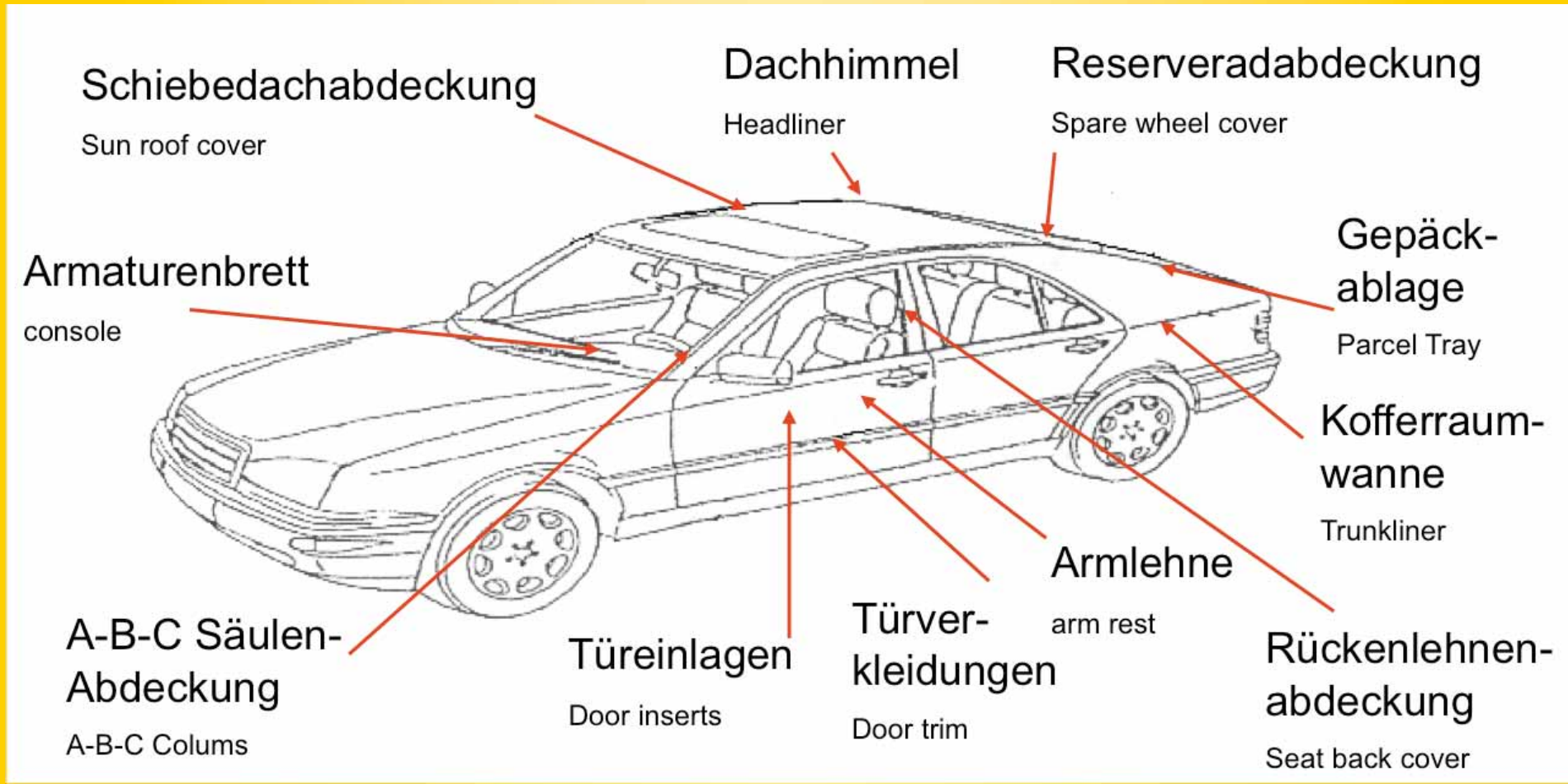
Processing advantages

- **Cost reduction - procedures and resources (“one shot”)**
- **Weight reduction (up to 30%)**
- **High energy absorption (side impact), high noise absorption**
- **Good mechanical properties and formability, good stiffness, good strength and impact resistance, no shrinkage**
- **Very minor odour emissions (fogging)**
- **Low burning rate**
- **No „contact squeaking“ (unlike PC/ABS)**
- **Good recycling possibilities (EU End of Life Vehicle Directive), for example as PP-NF-granule**
- **NEW: More flexible, more different parts, ten years lasting**

Source: R+S, 2004

Press Moulding

„One Shot“-process, applications



Quelle: R+S, 2004

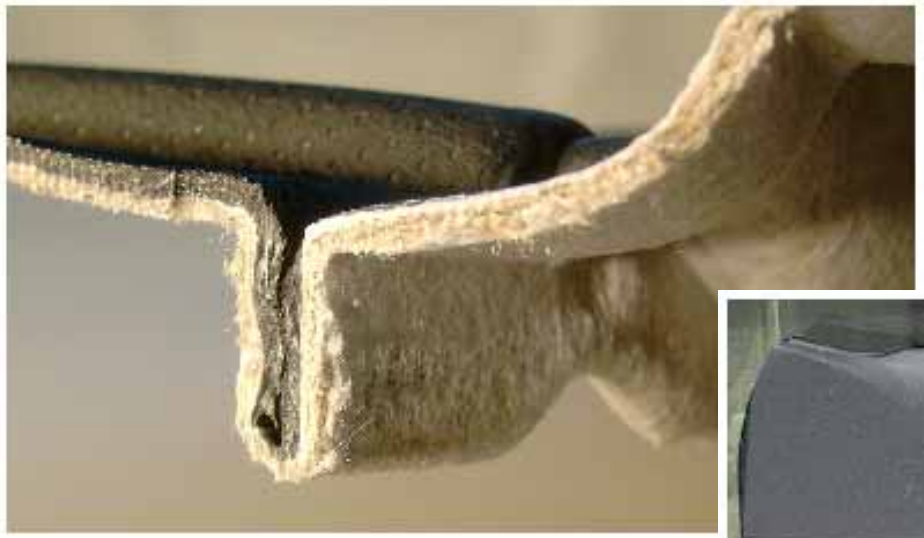
Beispiele

Mondeo 2001

insert: KENAF/PP

door frame: injection moulded PP

Two different decores in one step!



Quelle: R+S, Ford 2004

Wood and cotton

Wood fibres

27,000 t wood fibres in 40,000 t composites
(Estimate of 2005 (nova 2006))

Cotton

45,000 t cotton fibres in 79,000 t composites, mainly in lorry driving cabs.
(Estimate of 2003 (nova 2004))

Source: nova-Institut 2008, MAN 2008

Furniture

Resin-Transfer-Moulding (RTM) Technique

Table board
from resin-bounded natural fibres

Lamp shade
3-dimensional, translucent

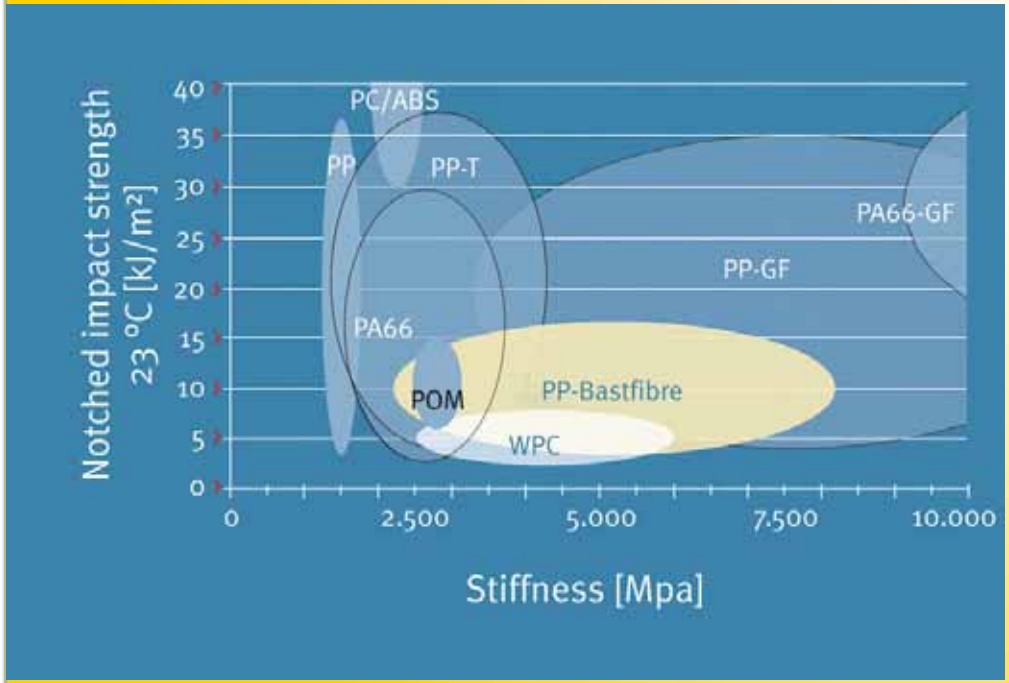
Source: NPSP 2007, nova-Institut 2007

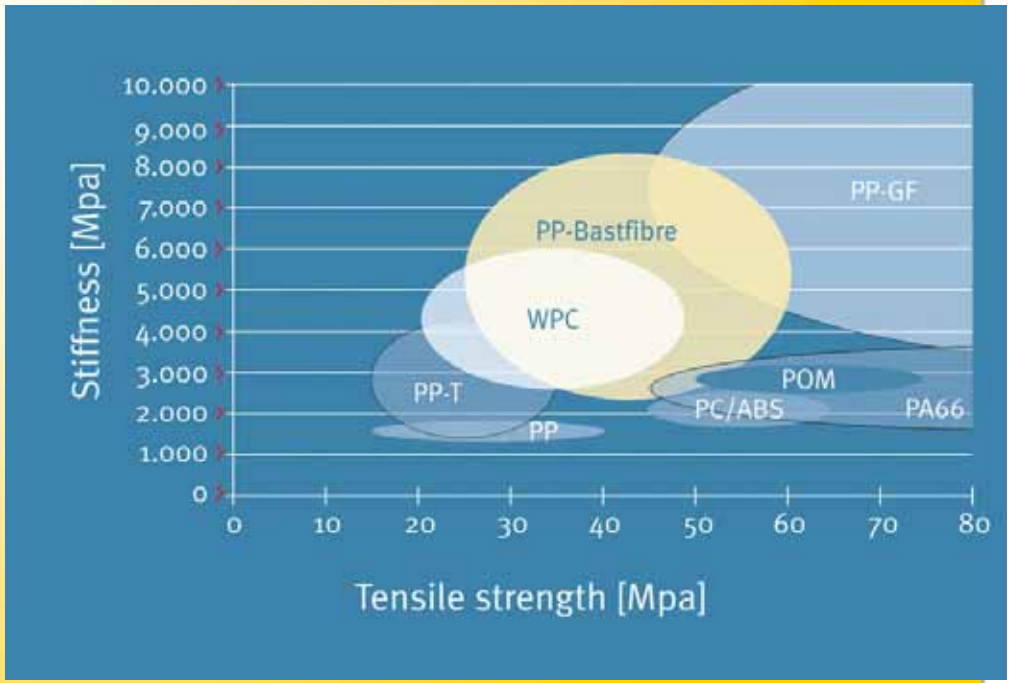
Injection moulding: PP-NF and WPC in comparison I

Significant increase in stiffness, stability and tensile strength through wood and natural fibres

Level between filler materials (talcum) and reinforcing fibres (glass); GF level can be achieved by the best PP-NF.

Low impact strength, increase possible through adding elastic fibres.





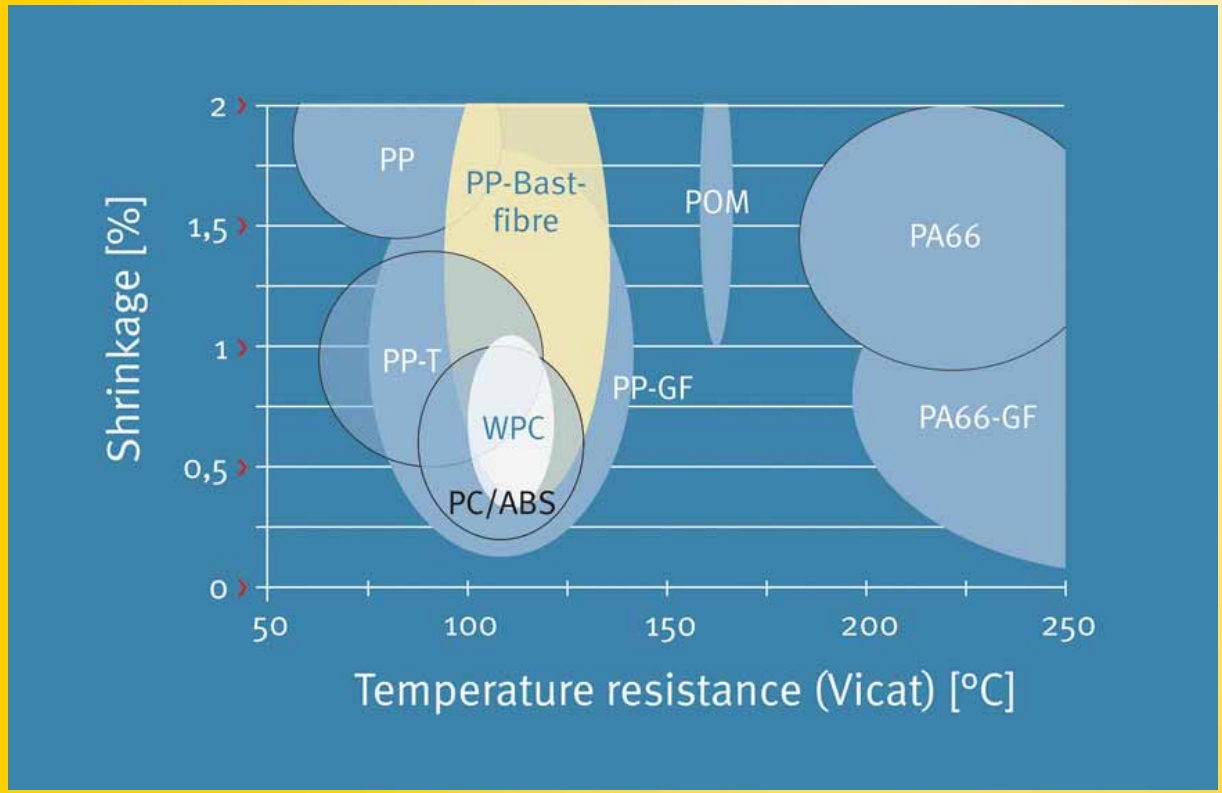
Injection Moulding: PP-NF and WPC in comparison II

Increased processing temperature through natural fibre reinforcement

Processing temperature higher than the one of PP-T, same level as PP-GF

Some WPC / PP-NF show a markedly good shrinkage behaviour equal to PC / ABS

Contrary to glass fibre reinforcement, almost isotropic shrinkage



Minor tendency to burst

Good accoustic quality

Contrary to PC/ABS no static noises

Minor abrasion

Lower density than glass fibre reinforced polymers

Approved for use with foods

Automobiles

NFRP injection moulding

Natural fibre proportion 20 to 50 %

Mostly hemp fibres

Numerous possibilities, e.g. back-extruding of textiles

Technology with a high potential

Audi

Glove box, first NFRP series unit (Audi A2)

MöllerTech

New developments

Source: nova-Institut 2008

Industrial and consumer goods

Example: Grinding disc

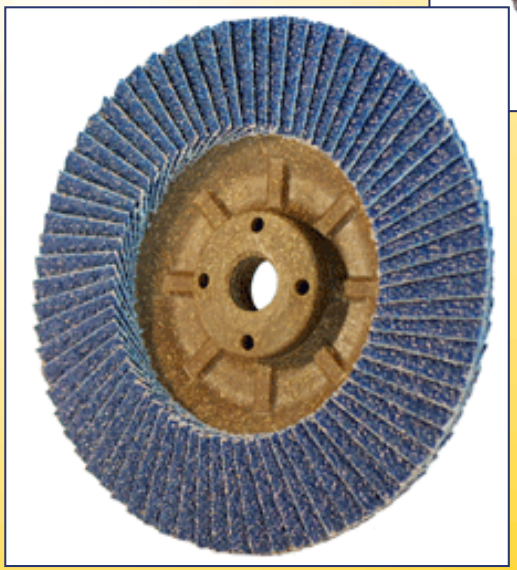
Flexible grinding disc with an injection-moulded PP-hemp fibre joist

Good mechanical properties

Labour protection advantages

Recycling advantages

Successful market introduction: Production volume more than 1 mio./year



Source: nova-Institut 2006

Industrial and consumer goods

Example: Cosmetics packaging

Packaging refill: Recycled paper pulp

Lipstick casing and brush: Flax-PP

Successful series on the USA market for over 4 years

Follow-up model: Lipstick casing from recycling resin

Source: Aveda 2007, nova-Institut 2008

Industrial and consumer goods

Example: Funeral articles (urn)

Noble look

Ash capsule with a not to be opened clip fastening

Natural fibres with PLA bioplastics

Decays in typical environment / biodegradable

Urn
from non-woven material, compression moulding

Urn and ash capsule
from granulate, injection moulding

Source: Linotech 2007, nova-Institut 2008

Innovation: Multispot & SabiDekor (Hemp-PP)

PP-hemp fibre granulate

Fibre proportion only 2 to 5 %

Fibre length < 1 mm

Partly coloured:

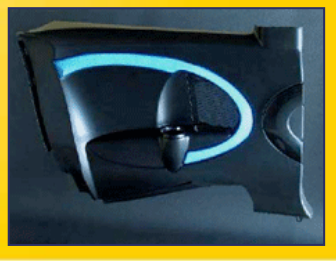
– Transparent –> Ambience illumination

– Opaque –> Marbling

– Metallic –> Depth effect

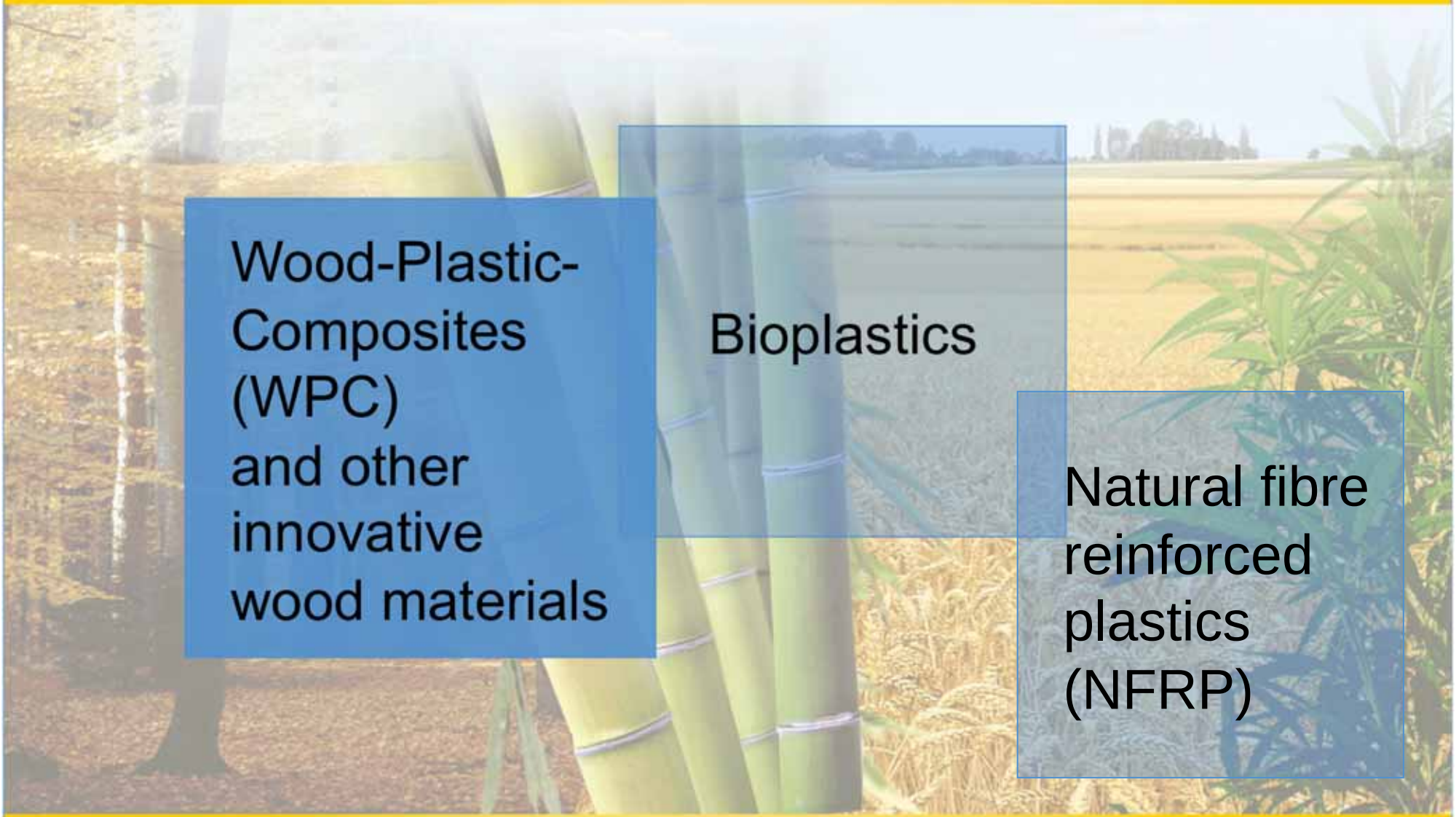
Specification test for automobiles

Hot light ageing
(DBL 5404, requirement note 4 / 4th cycle)



Source: MöllerTech 2008

WPC


Wood-Plastic-Composites (WPC) and other innovative wood materials
Bioplastics
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The most important markets for WPC

Automobiles – Construction and Furniture – Industrial and Consumer Products

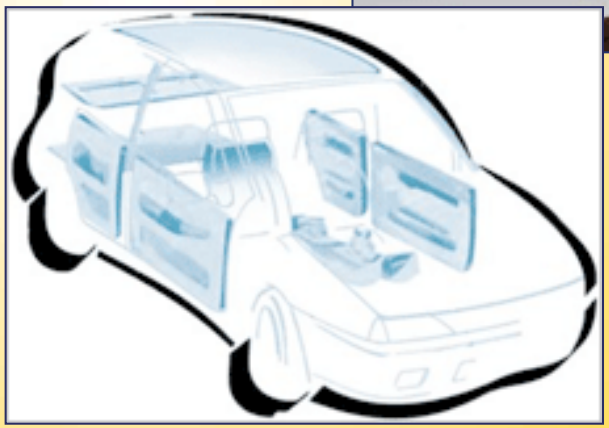
Source: Werzalit 2007, nova-Institut 2007, IKEA 2007, Domna 2008

Automobiles

Thermoforming & injection moulding

- Little distortion
- Good thermal shock resistance
- Low processing temperature (low energy demand, short cycle time, low textile damaging with back-extruding
- Little abrasion
- Good acoustical properties

Loudspeaker enclosures
and other WPC units (partly in series production (Audi))



WPC Thermoforming
Serial units in passenger cars (various models)

Source: Renolit 2007, Werzalit 2007

Deckings

Extrusion

- Floorboards
- Underfloor constructions
- Cover strips
- et cetera

Injection moulding

- Coffered deckings
- Fixing material
- et cetera

Source: nova-Institut 2007, Werzalit 2007

First seal of approval for WPC deckings

After inspection to be assigned to manufacturers of deckings from wood-polymere-materials (WPC)

"Qualitätsgemeinschaft Holzwerkstoffe" is an approved inspection and certification body of "Deutsches Institut für Bautechnik (DIBt)"

Notified body of the EU (Certification body of CE marking of wood materials according to DIN EN 13986); identification no. 1344

Quality properties of the seal of approval:
– Requirements on raw materials
– Requirements on product properties
– Manufacturer warranties may deviate upward

Source: VHI 2007, Kosche 2007

Future market China – The awakening of a giant

- Rapid development, approx. 250 actors, 140 of which are manufacturers
- Production volume 2006: approx. 75,000 t/a, but for Olympia buildings alone, approx. 80,000 t were used, estimate 2007: 150,000 t
- Less wood fibres, more „biomass“ (bamboo, corn stalks, rice husks etc.) –> European quality demands are tough / cannot be met
- Fibre proportion is 40 to 60 % on the average
- Most common polymeres: PE and PVC
- Favourable factors of production and low material costs, but (still) low production speed

Parts of the promenade against the backdrop of the Oriental Pearl Tower in Pudong / Shanghai.

Source: nova-Institut 2007, Eder 2008

Future market China – Innovative applications

Source: CWPCU 2008

Furniture

Extrusion

- Extruded shelves
- Constructive elements
- Decorative and handle strips

Injection moulding

- One- or multipart furniture
- Upholstery support
- Handholds, handle shells, small parts
- Connecting elements

Other

- Panel materials
- Thermoforming
- Rotation moulding

Source: Maschinenbau Kitz 2006, IKEA 2007, Korte 2007

Industrial and consumer goods

Injection moulding

- Advertising material, office supplies
- Urns, flower pots
- Functional parts
- Pallets, packing material
- Tableware

Extrusion

- Baseboards
- Snail prevention fence

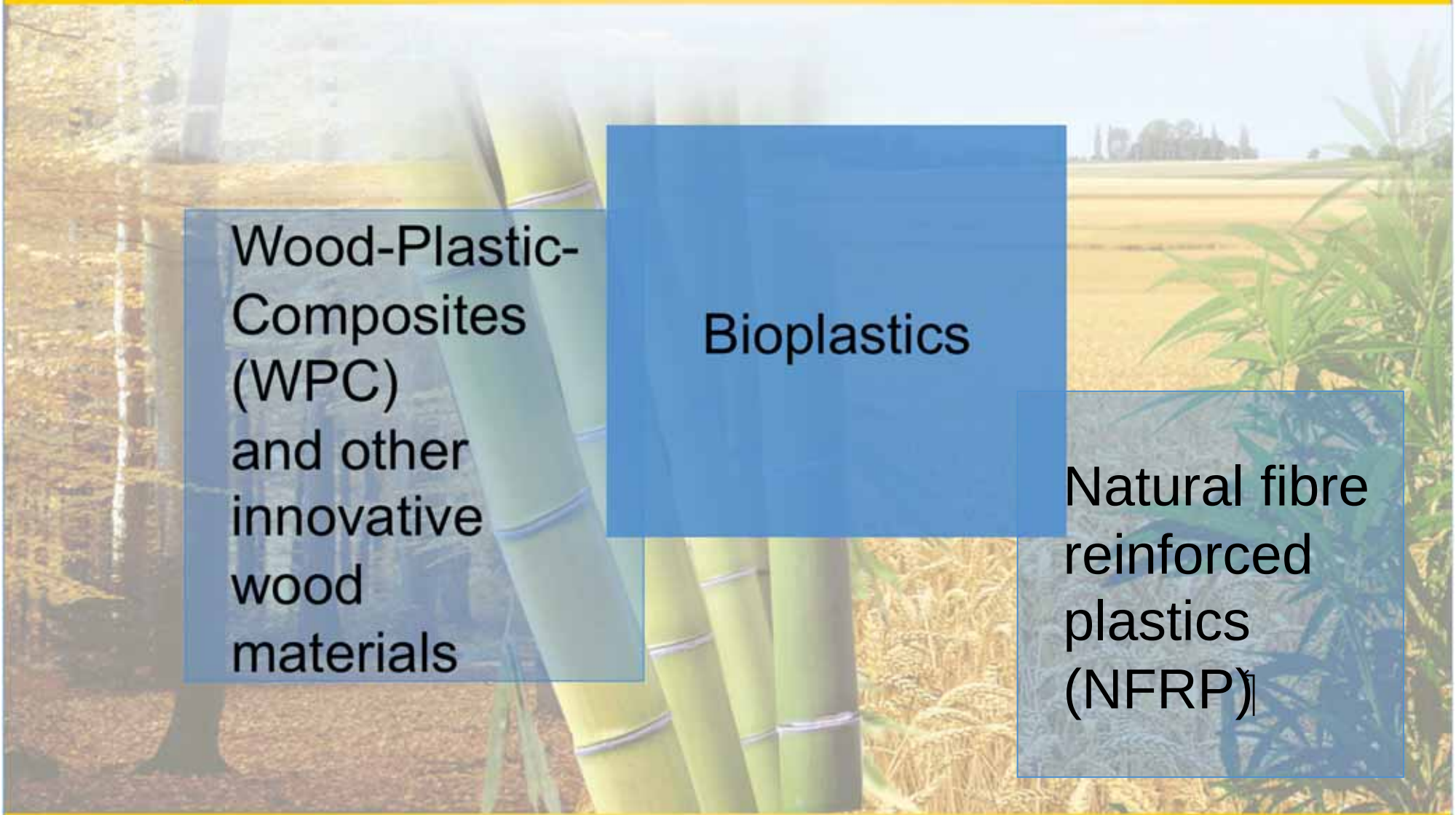
Source: nova-Institut 2007 & 2008, Licno 2007

Market volume WPC

	Europe	Germany	North America	USA	Japan	China
1998	–	–	–	100,000 t [1)]	–	–
1999	–	–	–	–	14,000 t [7)]	–
2000	3,000 t [2)] -50,000 t [3)]	–	135,000 t [3)]	200,000 t [1)]	22,000 t [7)]	–
2002	15,000 t [1)]	–	–	–	–	–
2003	20,000 t [4)] 25,000 t [1)] 30,000 t [2)]	–	600,000 t [5)]	400,000 t [2)]	30,000 t [6)]	–
2004	–	5,000 t [8)]	–	–	–	–
2005	40,000 t [11)] 100,000 t [10), 14)]	10,000 t [9)]	700,000 t [10)]	–	35,000 t [12)]	–
2006	50,000 t[11)] 100,000 t [16)]	–	–	–	40,000 t [12)]	75,000 t [17)]
2007	120,000 t[16)]	20,000 t[13)]	–	–	50,000 t [12)]	150,000 t [17)]
2010	270,000 t [14)]	116,000 t [15)]	1.6 Mio. t [14)]	–	100,000 t [14)]	200,000 t [16)]

1) Kaczmarek & Wortberg 2003; 2) AMI 2003; 3) Eder 2003;
4) Kirsch & Daniel 2004;
5) www.american-recycler.com (01/2004); 6) pers. Mitteilung Kikuchi, T. (EIN) 2005; 7) Kikuchi, T. (EIN) 2002; 8) nova 2005: WPC-Studie; 9) nova 2005: WPC-Studie (Prognose);
10) Hackwell & Pritchard 2005, Update 2006; 11) Nash (AMI), zitiert nach: Holz- und Kunststoffverarbeitung (HK) 1–2/06; 12) Kikuchi, T. (EIN): „WPC: Marketing und Normen in Japan“, 6th Global Wood and Natural Fibre Composites Symposium, Kassel 2006; 13) nova/Korte 2006 (Prognos);
14) Eder 2007: WPCs – An Updated Worldwide Market Overview Including a Short Glance at Final Consumers, Bordeaux 2007;
15) Carus & Müssig 2007 (verändert); 16) nova 2007;
17) Gahle, Carus, Eder 2007/08.

Bioplastics



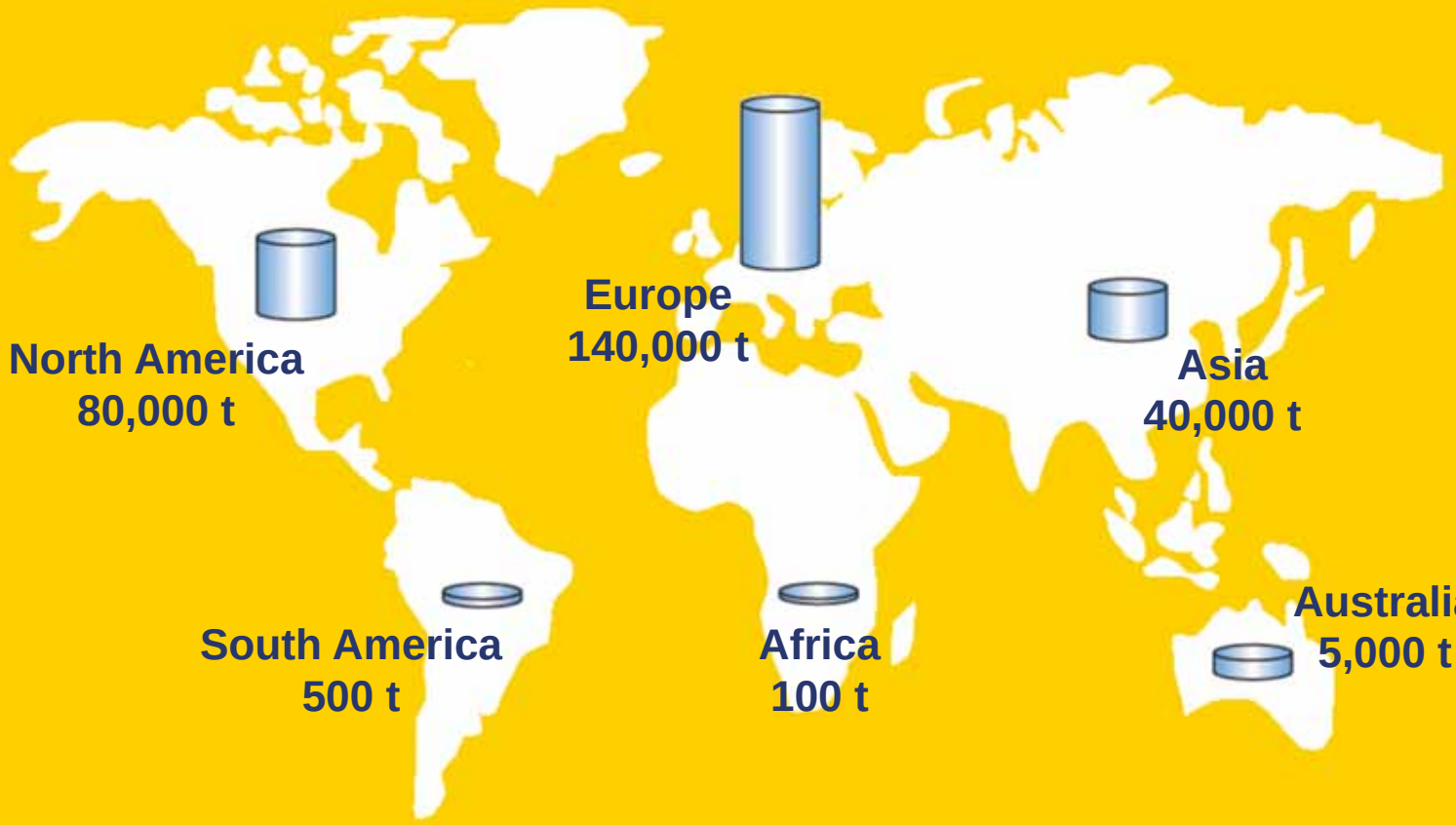
The most important markets for bioplastics

Packaging – Automobiles – Industrial and Consumer Goods

Source: FKuR 2008, Novamont 2007, Plantaplast 2008

Worldwide production capacities of biodegradable bioplastics

Actually available max. capacities 2007: 265,000 t/a

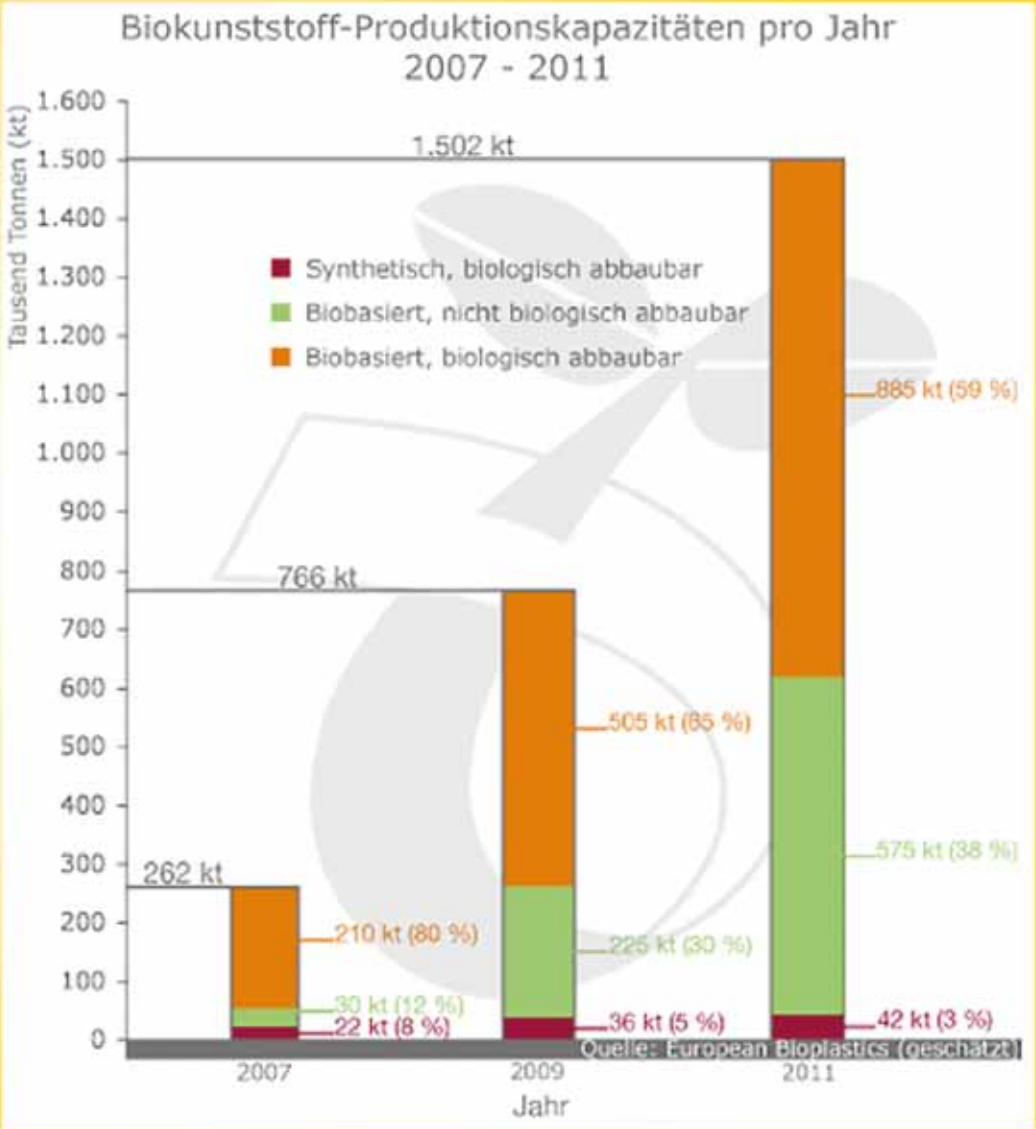


Source: nova 2007, the study was conducted by nova-Institut GmbH (Hürth) and partners – on behalf of Reifenhäuser GmbH & Co. KG Maschinenfabrik (Troisdorf), 2007

Trend: Growth in bio-based bioplastic

In 2007 it was forecasted that non bio-degradable bioplastics will have the highest growth rate

Growth mainly in the bio-based sector



source: european bioplastics

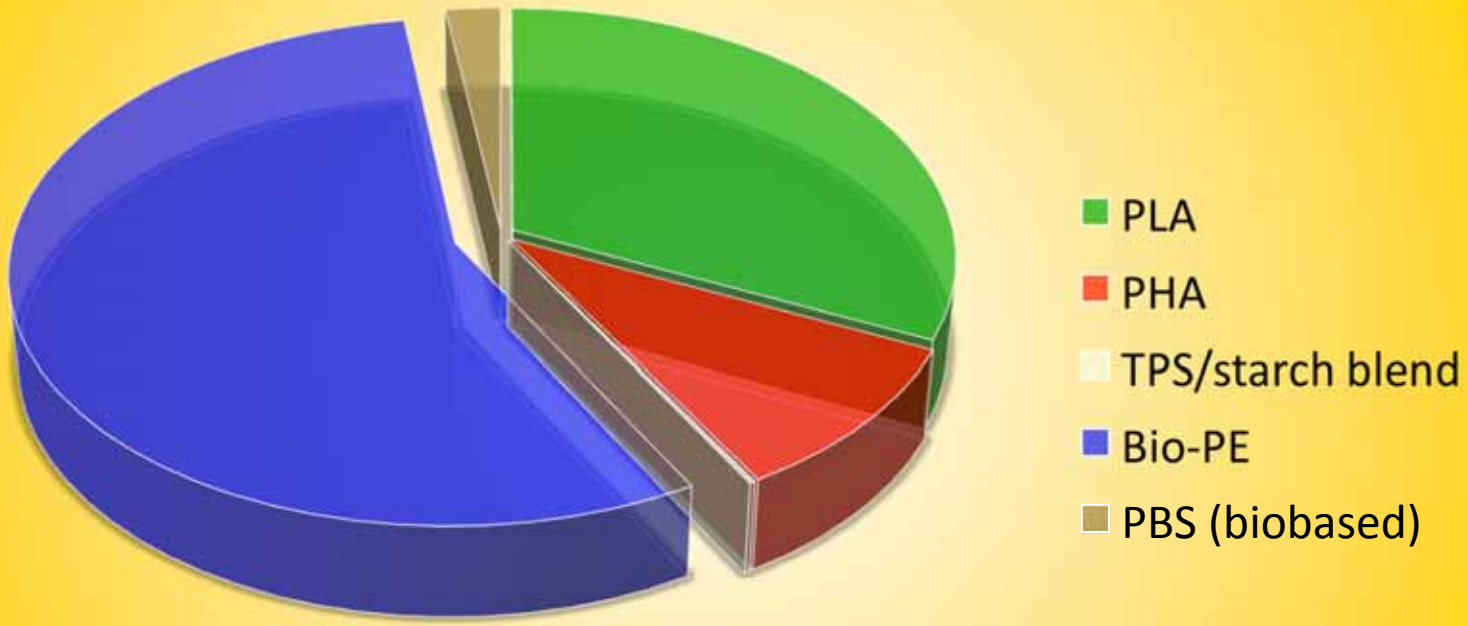
Additional production capacities for bioplastics, development since 2007*

	Capacity 2007					**350,000**
	Continent	Until end 2008		Until 2010, under construction		
		material	amount	material	amount	
	Asia	Lactic acids and lactates (PLA)	100,000	PBS, biobased	10,000	113,000
		PHA	2,000			
		TPS/starch blend	1,000			
+	Europe			PLA	71,500	73,500
				succinic acid	2,000	
	North America			PHA	50,000	50,000
	South America			Bio-PE	300,000	300,000
	Sum		**103,000**		**433,500**	**536,500**
=	**2008:**		**453,000**	**2010:**		**886,500**

*conservative assumptions, all in metric tons

Source: nova Institut

The new capacities by sort (until 2010)

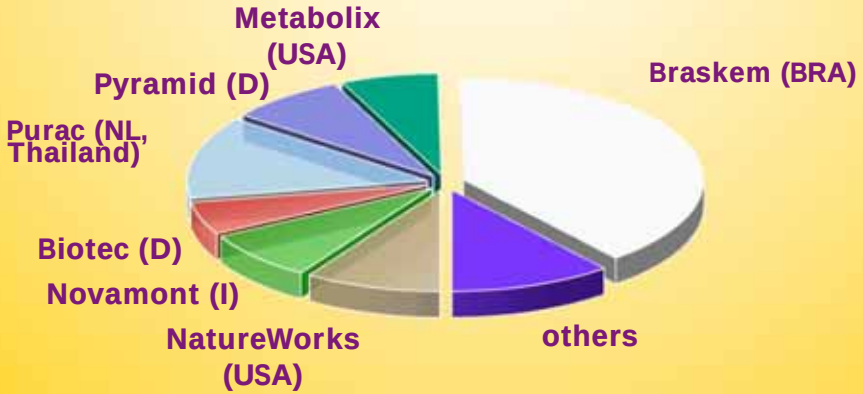


source: nova-Institut

The structure of producers worldwide (by capacities)

The main new players

Purac (NL):	built ca. 100,000 t/a (lactic acid, lactates) capacity in Thailand
Pyramid bioplastics (D):	ca. 60,000 t/a (PLA) under construction
Braskem (BRA):	ca. 300,000 t/a (biobased PE) under construction
Metabolix (USA):	ca. 50,000 t/a (PHA) under construction



New players enter the market with big capacities

source: nova-Institut, narocon

Packagings
(biobased and) biodegradable:
Starch, TPS, PLA, PHA / PHB, cellulose, blends etc.

Markets:

- Carrier bags
- (Compost) bags
- Food packagings
- Bottles
- Packaging material, filler material
- „Seedling“ as an international seal for proven compostability

Source: nova-Institut 2007

Industrial and consumer goods biobased and partly biodegradable:

Straight vegetable oils, resins, natural rubber, starch, PLA etc.

Markets

- Foams, mattresses
- Textiles
- Catering
- Electrical devices (mobile phones, MP3 players etc.)
- Writing utensils, ball-point pens
- Sporting goods and toys
- Mulch films, planting pots
- Cosmetic and sanitary products
- Credit cards
- Medical engineering (implants etc.)

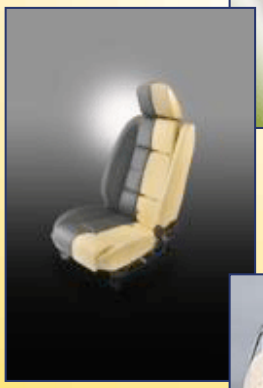
Source: Novamont 2006, Samsung 2008, nova-Institut 2007, Nature Works 2004, 2005

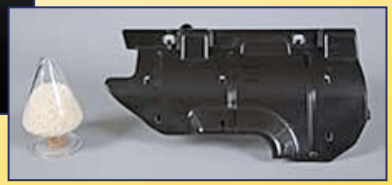
Automobiles
biobased and non-biodegradable:

Straight vegetable oils, resins, natural rubber, starch, PLA etc.

Markets:

- Tyres
- Foams (seat upholstery)
- Moulded parts
- Car mats
- Interior
- etc.





Source: Novamont 2007, Laer 2007, Cargill 2008, Mazda 2006, John Deer 2007

In detail: Bioplastics in the automotive industry

Biopolymers – more than just in the starting blocks!

Selected examples I

- **Ford, USA:** Foamed plastics with a 40% soy proportion for seats, head rests and arm rests, introduced 2006.
- **DuPont, USA:** Sorona-Biopolymer with a 37% renewable resource proportion, market introduction middle of 2007. The material is injection moulding compatible and needs 40% less production energy.
- **Mazda, Japan:** May 2006 introduction of bioplastics for automobile interior, 88% PLA (made of crop) and 12% crude oil based. Considerably better mechanical and thermal properties than PLA.
- **Toyota, Japan:** Already since 1998 PLA (in mixture with PP) in dashboard applications for the Japanese market in the design models PRIUS and RAUM. Internal PLA production (1,000 t/y) for automotive and non-automotive applications – outlook: in the year 2020 biopolymers 20% (turnover 38 bn. US-$) of the worldwide polymer production.
- **Mitsubishi, Japan:** PBS made through fermentation of sugar in combination with bamboo fibres introduced in 2006 („Green Plastic“); Life cycle CO_2 emission about 50% lower than petro-chemical substitute.

Source: nova 2007

In detail: Bioplastics in the automotive industry

Biopolymers – more than just in the starting blocks!

Selected examples II

- **Honda, Japan:** „Bio-Fabrics“ – textiles for the automotive interior and seats. Use of PPT (Polypropylen Terephthalat) as a materials, which is produced via polymerisation of 1-3PDO (Propandiol) on corn basis (DuPont, Tate & Lyle) and a petrochemical component.
- **Goodyear, USA:** The tire BioTRED is produced using „nano-droplets of a complexed starch“ and is available on the market as GT3 (Europe) and GT-HYBRID and EAGLE LS3000 (Japan). Low production energy, reduced rolling resistance and 5% fuel savings.
- **Arkema, USA:** Rilsan PA11 is a high performance polymer with a ricinus oil base with similar properties to Polyamid 12. It was awarded the label „Biomass Based“ in Japan in 2006. Currently the company offers a complete fuel line system for biodiesel – it has already been approved in Europe and Brazil. The greenhouse gas savings are about 40%.
- **Polytec-Automotive, Deutschland:** Introduced in 2006 a prototype of a trunkliner for the new Audi A4 which consists completely from renewable resources – sugarcane resin/furan instead of PU, jute instead of fibre glass.

Source: nova 2007

In detail: Bioplastics in the automotive industry

Biopolymers – more than just in the starting blocks!

Selected examples III – soy based foams

- No effect on costs
- Improved properties compared to synthetic foams
- Applicable with minimal production modulations
- Approx. 15 kg of foams in every vehicle
- Applications: seats, head rests, arm rests, headliner etc., but also parcel tray and bumpers
- Many well known providers (Cargill, Lear and at least six more)

Source: Gord Surgeoner and Mohini Sain 2008

Outlook

On which resources and materials should the manufacturing industry rely in the future?

Biomaterials do have a bright future!

Price development and availability of agricultural resources clearly less critical than with fossile resources; large available agricultural areas can be activated.

Big substitution potential and technical additional benefit.

Two-digit growth every year.

Bioplastics:
„bioplastic & food“- big discussion without a real problem – but this is another presentation!

Thank you for your attention.

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