



Development of an industrial natural-fibre-pellet production for the use of natural fibres as reinforcement of (bio-)plastics in injection moulding and extrusion

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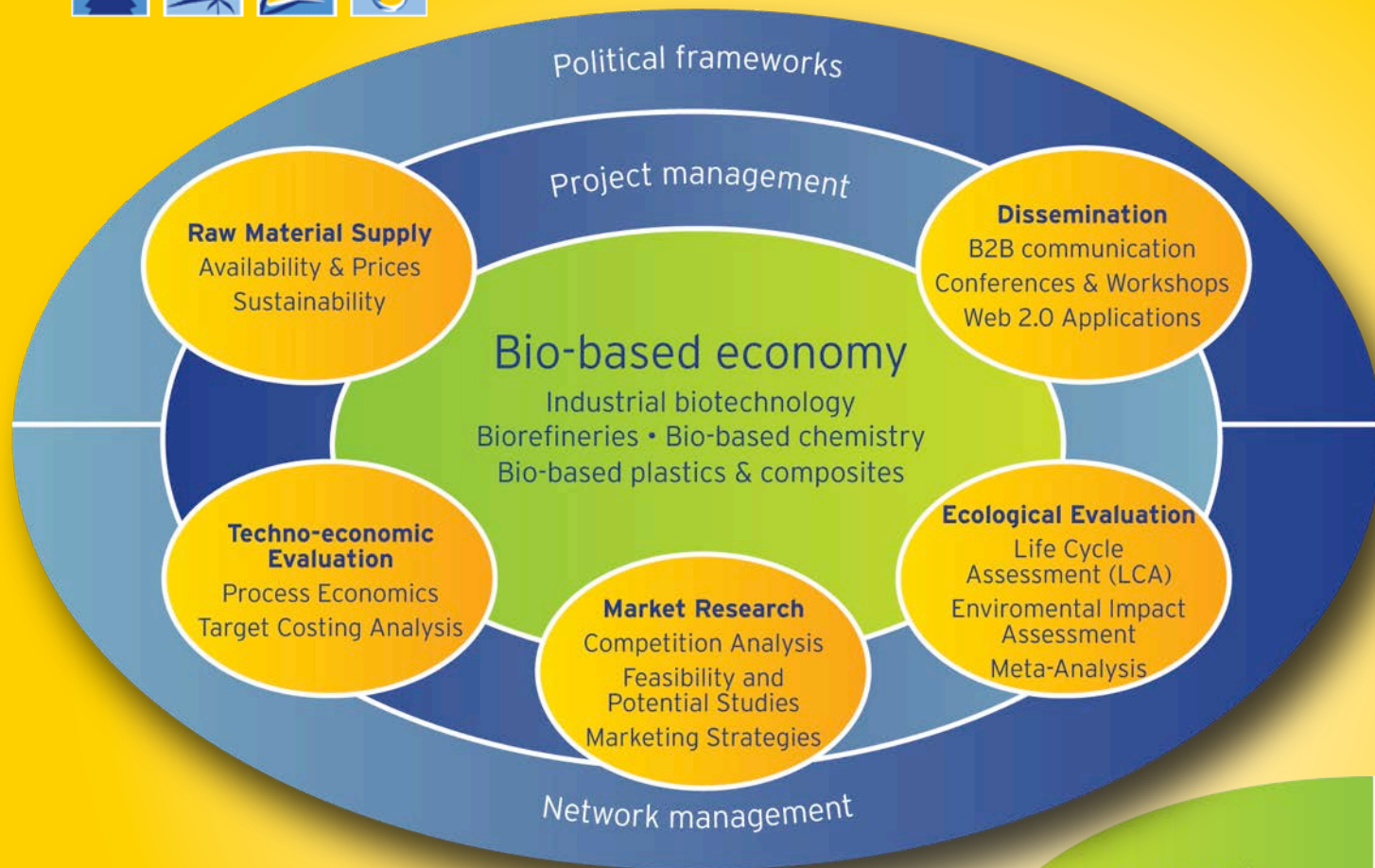
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Bio-based Economy – Bio-based Chemistry and Materials



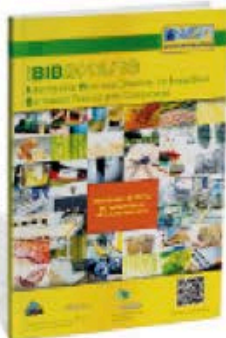
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Field of activity

- ☐ Renewable Raw materials
- ☐ Bio-based Plastics for disposable applications
- ☐ Bio-based Plastics for durable applications
- ☐ Elastomers / Natural Rubber
- ☐ Natural fibre reinforced plastics
- ☐ Wood Plastic Composites and other Cellulose-reinforced plastics
- ☐ Green Additives
- ☐ Other

Application area

- ☐ Agriculture & Horticulture
- ☐ Automotive
- ☐ Building and Construction
- ☐ Consumer electronics and electronics
- ☐ Consumer goods
- ☐ Household articles and toys
- ☐ Packaging
- ☐ Personal hygiene
- ☐ Other

Products

- ☐ Precursor
- ☐ Granules
- ☐ Semi-finished goods
- ☐ Finished goods
- ☐ After treatment
- ☐ Other

Renewable Raw Materials

- ☐ Base chemicals
- ☐ Building blocks
- ☐ Natural fibres
- ☐ Wood and other cellulosic material
- ☐ Other

Plastic types

Thermoplastics

- ☐ Cellulose based
- ☐ Lignin based
- ☐ Polybutylene Adipate Terephthalate (Bio-PBAT)
- ☐ Polybutylene Succinate (Bio-PBS)
- ☐ Polyethylene / Polypropylene (Bio-PE / PP)
- ☐ Polyvinylchloride (Bio-PVC)
- ☐ Polylactic Acid (PLA)
- ☐ Polyhydroxyalkanoates (PHA)
- ☐ Polyamides
- ☐ Starch based
- ☐ Other Thermoplastic Polyesters
- ☐ Other Thermoplastics

Thermosets

- ☐ Polyurethane (PU)
- ☐ Epoxy
- ☐ Unsaturated Polyesters
- ☐ Other resins

Foams

- ☐ Thermoplastic foams
- ☐ Thermoset foams
- ☐ Particle foams
- ☐ Other

Elastomers

- ☐ Thermoset Elastomers
- ☐ Thermoplastic Elastomers

Green additives

- ☐ Adhesive agents / Glues
- ☐ Anti yellowing
- ☐ Binder / Emulsifier
- ☐ Chain extenders
- ☐ Coatings / Lacquers / Finish
- ☐ Colours / Pigments
- ☐ Denesting aids
- ☐ Flame retardant
- ☐ Impact modifiers
- ☐ Plasticizer
- ☐ Processing aid
- ☐ Protection against biological infestation
- ☐ Stabilizers
- ☐ Other

Special Properties

- ☐ Antistatic
- ☐ Breathability
- ☐ Bio-degradable (DIN EN 14851/2)
- ☐ Compostable (DIN EN 13432)
- ☐ Flame retardant
- ☐ Food safe
- ☐ Insulating
- ☐ Odour free
- ☐ Thermostable (over 100 °C)
- ☐ Vibration- and sound-isolating
- ☐ Water resistant
- ☐ Other

Processing types

- ☐ Blow moulding
- ☐ Blown film extrusion
- ☐ Calendering
- ☐ Compounding
- ☐ Compression moulding
- ☐ Extrusion
- ☐ Film extrusion
- ☐ Injection moulding
- ☐ Prototype building
- ☐ Special processing
- ☐ Thermoforming
- ☐ Other

Research & Development and Consultants

- ☐ Biotechnology
- ☐ Chemical research
- ☐ Technical / Process-related research
- ☐ Life Cycle Assessment / Sustainability Studies
- ☐ Market Research and Development / Consultancy
- ☐ Publication

Suppliers, Engineering, Associations and Agencies, R&D and Consultants





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Pictures (left to right): Teijin, Polyone, Staedtler, Propper, Biotex, Fujitsu, Werzalit

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TYPICAL NEWS

- **NEW** Clariant plans acquisition of Süd-Chemie AG [2011-02-16]
Cooperation to focus on innovation and growth in emerging markets
- **NEW** Clariant AG plant Erwerb der Süd-Chemie AG [2011-02-16]
Zusammenarbeit soll Forschung in den Zukunftsmärkten Neue Materialien und Biotechnologie stärken
- **NEW** Novozymes sucht zweites Standbein im Biobusiness [2011-02-16]
Kauf der EMD-Agrosparte des Chemiekonzerns Merck KGaA erlaubt neue Wachstumsziele
- **NEW** LANXESS steps up commitment to biobased raw materials [2011-02-15]
10-year exclusive supply agreement with Gevo
- **NEW** Coca-Cola says biodegradable packaging 'not a viable option' [2011-02-15]
New report from Zenith International finds not all manufacturers to agree with



Fachtagung 21. Mai 2012

Maternushaus Köln,

Teilnahmegebühr: 50.- Euro

fußläufig vom Bahnhof:

Kardinal-Frings-Str. 1-3, 50668 Köln, Tel.: 0221 1631-0

Naturfaserpellets

für Spritzguss und Extrusion

Workshop und Fachtagung



9th International Conference of the European Industrial Hemp Association (EIHA)

May 23th – 24th 2012, Wesseling / near Cologne (Germany)



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more information: www.bio-based.eu



Natural Fibre Injection Moulding and Extrusion



Bio-Composites in the EU 2010 (in tonnes)

	Estimated Quantities in the EU 2010	Forecast EU 2020 (under favourable political framework)
Compression moulding	190,000	370,000
- with natural fibres (flax, hemp, kenaf, jute, sisal, abaca, coir): (>95% automotive)	40,000	120,000
- with cotton fibres: automotive, mainly lorries	100,000	100,000
- with wood fibres (WPC): mainly automotive	50,000	150,000
Extrusion and injection moulding	172,000	550,000
- Wood Plastic Composites (WPC): construction, furniture, automotive, consumer goods	167,000 (incl. Norway & Switzerland)	450,000 (incl. Norway & Switzerland)
- Natural Fibres Reinforced Plastics: construction, furniture, automotive, consumer goods)	5,000	100,000
Bio-Composites in total	362,000 (= 14%)	920,000 (= 29%)
Composites in total (glass, carbon, natural fibres & wood)	2.5 Million	3.2 Million

Source: nova-Institut 2010 & 2011, AMI 2011, AVK 2010, Ellis, P. 2010



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

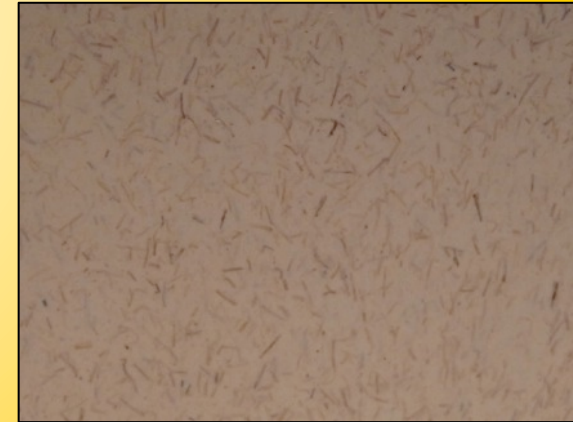
New developments



Ford Brazil 2009

Injection Molding

- Compound: Up to 50% of Recycled Polypropylene (PP) + 20% PP Prime + 30% Sisal Fiber)
- Application: Interior trim and non-appearance parts
- Allows weight reduction (according to application)
- Injection temperature reduced by 40° to 60° C
- Cycle time reduced by 15% to 30% depending on the tooling



Source: Ford 2009, nova 2009



Cases and Urns

Compressing and injection moulding

Mobile Phone Case
from
Kenaf Fibre
and PLA
(Japan)



FOMA-N701iECO



Urn from
Hemp Fibre and PLA (Germany)

Innovation



Cases, natural fibre and polypropylen, compress moulding (Germany). Pictures: Hempro International, Winter & Linotech



Urn, hemp fibre and bioplastics, compress moulding or injection moulding (Germany). Picture: nova-Institut



Industrial and consumer goods

Example: Grinding disc (producer: Eisenblätter, Germany)

- 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 3-4 mio./year



Picture: nova-Institut 2006



New Consumer Goods

Injection moulding



BioCharger (GreenGran, NL/China)
Jute Fibre PP Injection Moulding



Ironing board (Domena, France)
Hemp Fibre Injection Moulding



Tecnaro (Germany)

Injection moulding with natural fibres & Lignin (!)



Picture: Sergio Rossi, Gucci Group, Italien



Lautsprecher aus Arboform der Fa. Tecnaro GmbH, Bildquelle: Fraunhofer ICT



Lenkradsegmente mit lackierter
ARBOFORM Sichtoberfläche

Pictures: Tecnaro 2009

N026J: engineering grade

Property	Test Condition	Typical values	Unit
Melt Flow Rate	200°C, 10kg 2 mm die	5	g/10min
Density		1.11	g/cm ³
Flexural Strength	23°C, 50%	89	MPa
Flexural Modulus		4,900	MPa
Flexural Elongation		2.9	%
Deflection Temperature under Load	45N/cm	156	°C
	182N/cm	134	

GG N026J

Engineering grade. Granules based on polypropylene and natural fibres, which combines very high stiffness and strength with moderate impact strength. Its excellent thermal properties and dimension stability make it suitable for storage and use under high temperature conditions. Typical markets are within automotive-, construction-, and industrial applications.

Contact us for advice

It is not always easy to select the grade which most fit to your product specs. Our [experts](#) have a long tradition in polymer material properties, bio-plastics and how to process these into products. Please [contact](#) us for further help, or mail us: info@greengran.com.



P023J: 100% Bio-based engineering grade

Property	Test Condition	Typical values	Unit
Melt Flow Rate	190°C, 10kg 2 mm die	5.5	g/10min
Density		1.31	g/cm ³
Flexural Strength	23°C, 50%	105	MPa
Flexural Modulus		6,200	MPa
Flexural Elongation		1.8	%
Charpy impact, unnotched	23 °C, 50%	12	kJ/m ²
Charpy impact, notched		3	kJ/m ²

GG P023J

Fully bio-based engineering grade. Granules made from PLA and natural fibres, which combines ultra high stiffness and ultra high strength with moderate impact strength. Suitable for production of complex articles with long flow paths and thin walls. Excellent processability, good surface finishing, easy to mix with bio-based colour masterbatches. Typical markets are within toys-, consumer articles-, construction- and rigid packaging applications.

Contact us for advice

It is not always easy to select the grade which most fit to your product specs. Our [experts](#) have a long tradition in polymer material properties, bio-plastics and how to process these into products. Please [contact](#) us for further help, or mail us: info@greengran.com.





Latest trends in automotive: From flax to hemp

Price index: Hemp and flax technical short fibres



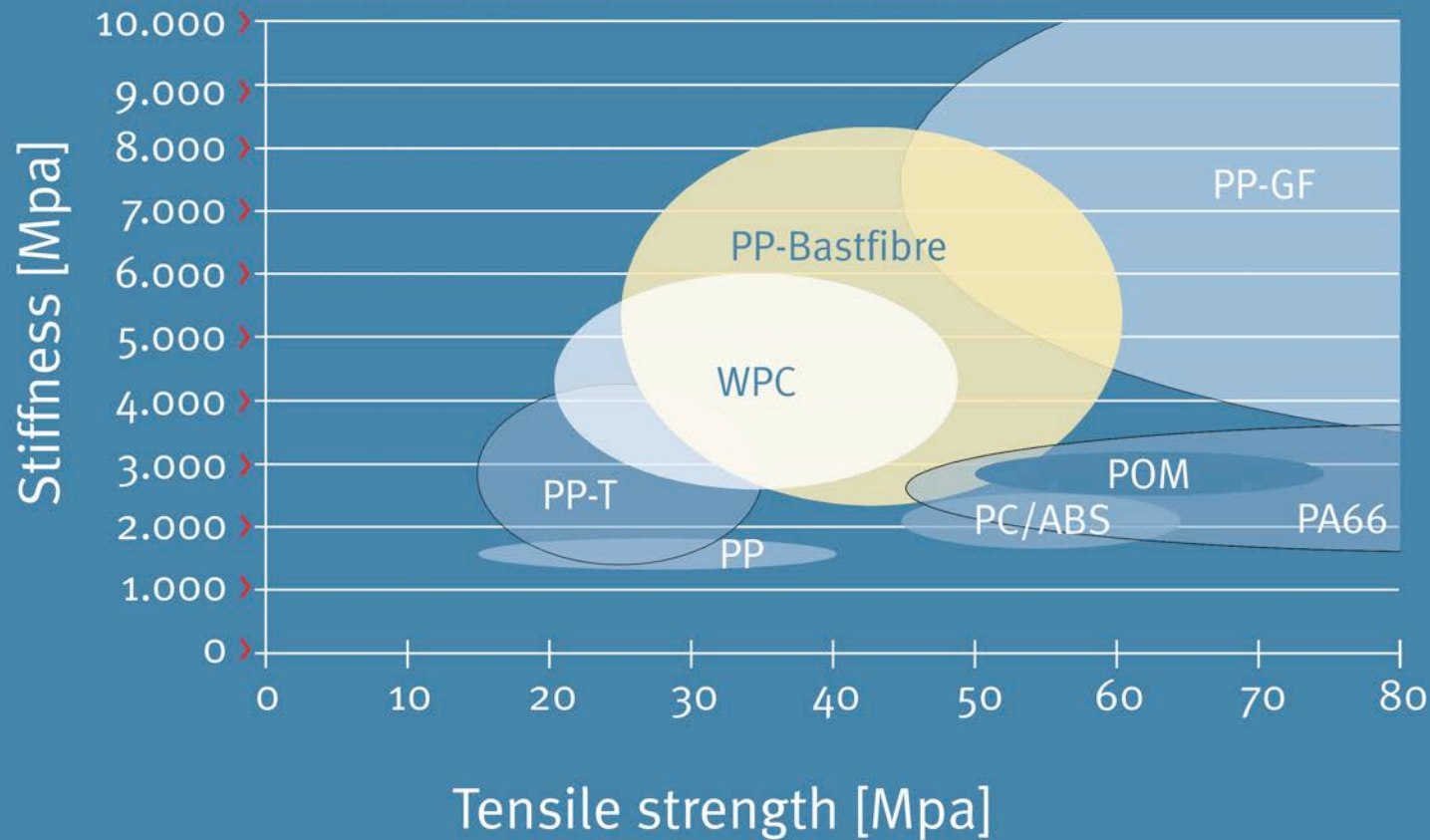


The most important factors for stiffness and strength as well as impact strength

- **Strength** of the wood or natural fibre
- **Aspect ratio** – ratio of length/diameter – filler or reinforcement
- **Fibre-Matrix-bonding** – the right bonding agent
- **Impact strength** – fibre length and fibre characteristics play a major role here and force-distance characteristic

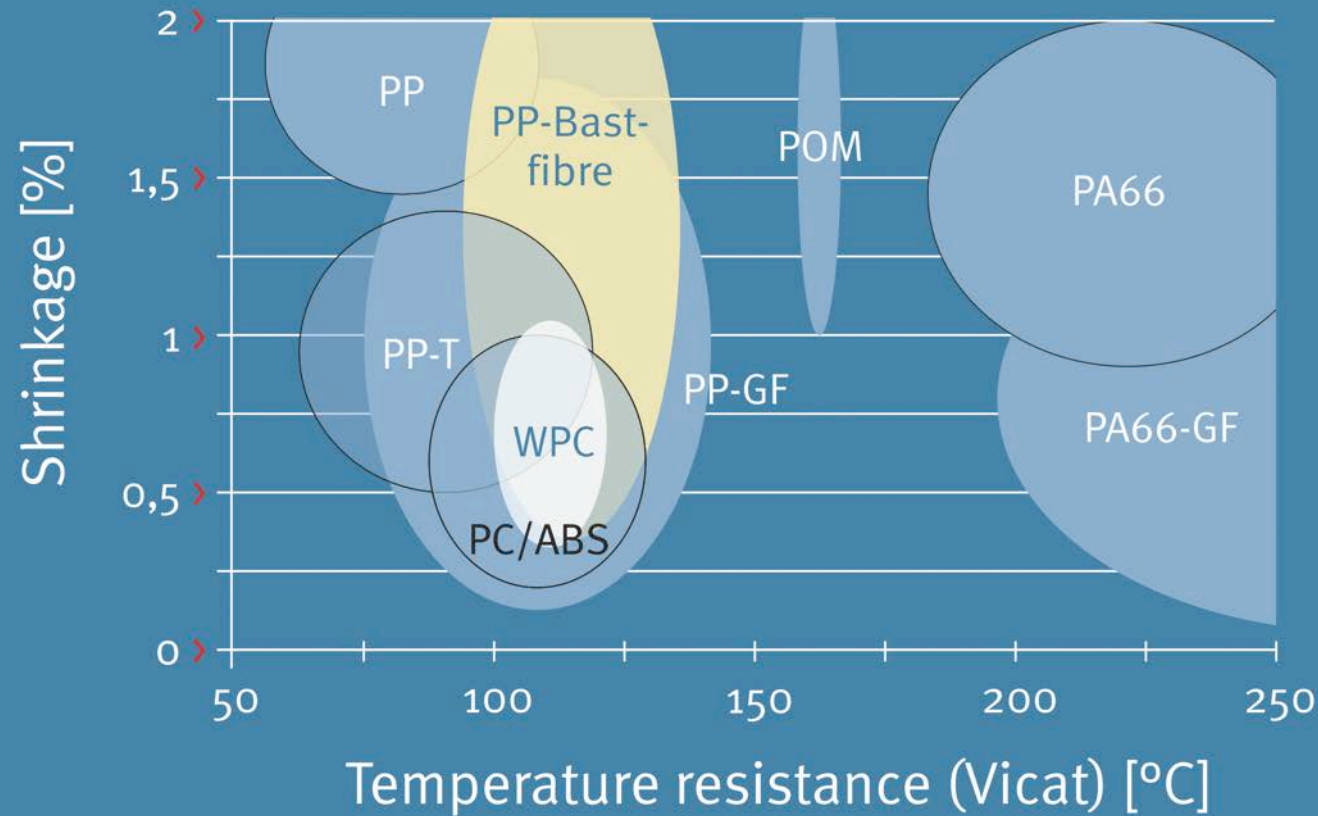


Injection Moulding - Mechanical Properties I



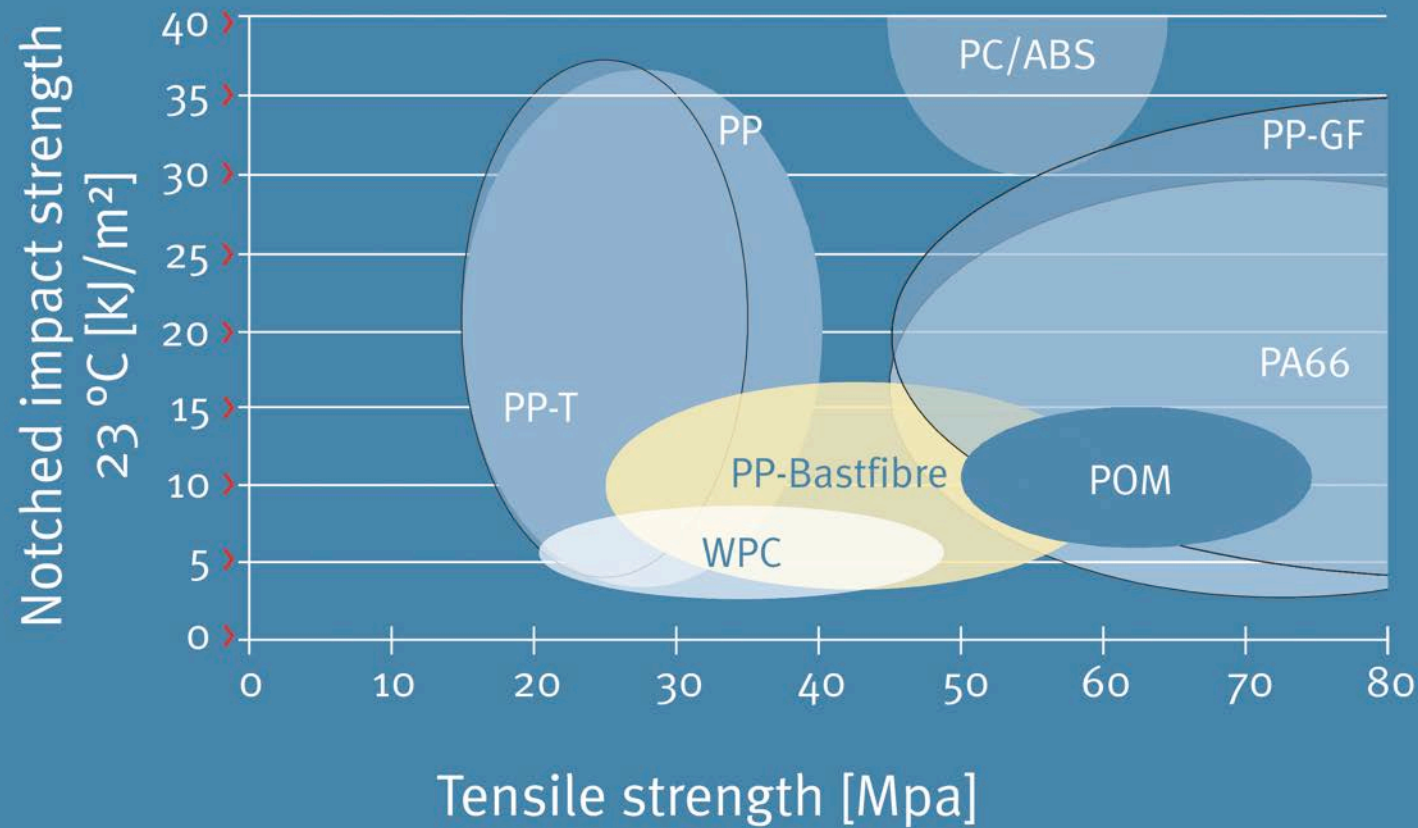


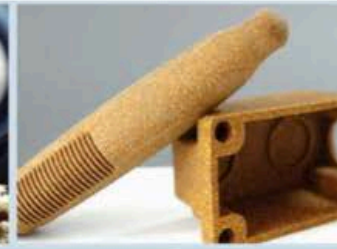
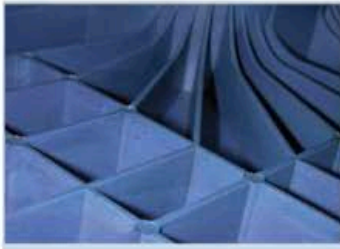
Injection Moulding - Mechanical Properties II





Injection Moulding - Mechanical Properties III





high potential for technical substitutions

summary: natural fibre injection moulding compared to other materials

Why is there a potential for technical substitutions?

- >> very low shrinkage at a low price
- >> good acoustic quality
- >> contrary to PC/ABS no static noises
- >> easy combination with other PP-based components
- >> minor abrasion
- >> higher stiffness and strength compared to non-reinforced polymers
- >> minor tendency to burst
- >> good thermal stability
- >> lower density than glass fibre reinforced polymers
- >> contrary to glass reinforced polymers approved for use with foods
- >> low processing temperature ($< 185^{\circ}\text{C}$)

Fibre-PP adhesion in literature & industry

Effect of MAPP on flexural properties of natural fibre-PP composites in literature.

Fibre, content	Reference	modulus (GPa)		strength (MPa)	
		PP	PP/MAPP	PP	PP/MAPP
Flax, 30%	Snijder, 2000			48	54-75
Flax, 30%	Keener, 2004			49	53-81
Flax, 30%	Bos, 2006	2.8-4.0	3.0-3.6	50	80
Flax, 50%			4.5-5.5	50	100

Effect of MAPP on tensile properties of natural fibre-PP composites in literature.

Fibre, content	Reference	E-modulus (GPa)		strength (MPa)	
		PP	PP/MAPP	PP	PP/MAPP
Flax, 30%	Keener, 2004			33	36-53
Flax, 30%	Bos, 2006	4.5	3.8-5.5	33	45-55
Flax, 50%	Bos, 2006		5.8-6.0		50-65
Hemp, 40%	Beckermann, 2007	4.8	4.3	31	38

- MAPP is best commercial solution to improve fibre-PP adhesion to date.
- MAPP can increase flexural and tensile strength of PP composites by 100 and 60%, respectively.

Plasma treatment in literature

Effect of plasma treatment on tensile properties of natural fibre-PP composites in literature.

		E-modulus (GPa)		Tensile strength (MPa)	
		Untreated	Treated	Untreated	Treated
20 wt.% wood	Yuan, 2004	2.7	2.9-3.3	22	25-27
20 wt.% sisal	Yuan, 2004a	2.6	2.9-3.1	22	24-26
20 wt.% hemp	Ragoubi, 2010	1.1	1.2	29	38
30 wt.% hemp	Ragoubi, 2010			23	32
30 wt.% wood	Belgacem, 1994	0.99	1.1-1.5	21 #	22-26 #
30 wt.% sisal	Martin, 2003	2.6	2.7	24	23
30 wt.% sisal	Martin, 2003	2.6	3.1	24	30

Fibre grade	Author	Power (W)	Voltage (kV)	Time (s)	Pressure (Pa)
sisal	Yuan, 2002	40-120		30-120	133-400
wood	Yuan, 2004	40-120		30	266
sisal	Yuan, 2004a	40-120		30	266
hemp	Ragoubi, 2010		15	900	'vacuum'
wood	Belgacem, 1994	15-35 mA	11-14	30-180	Not specified
sisal	Martin, 2003	200		150	35
HDPE	Martin, 2003	300		300	27
wood	Mahlberg, 1998	200		120-480	27
PP	Mahlberg, 1998	60-100		15-45	33-40

- Plasma treatment has positive effect on composite mechanical properties, however, all literature data found are based on low pressure and/or small reactor cells.



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Starting Point & Project Idea

- Domestic natural fibres like hemp and flax are not easy to be fed into the compounding process. This poses a big hurdle for an increasing use of natural fibres in the plastics industry.
- Usually modified fibres, special systems (die cut from fibre mats etc.) or card slivers (especially in R&D) are used, which are very process and cost intensive.
- The pelletizing of natural fibres could be an interesting solution: good dosing ability, good dispensing in the compounding process at acceptable costs. And: In case of success hundreds of granule producers could use natural fibres for their compounds.



Project Partners



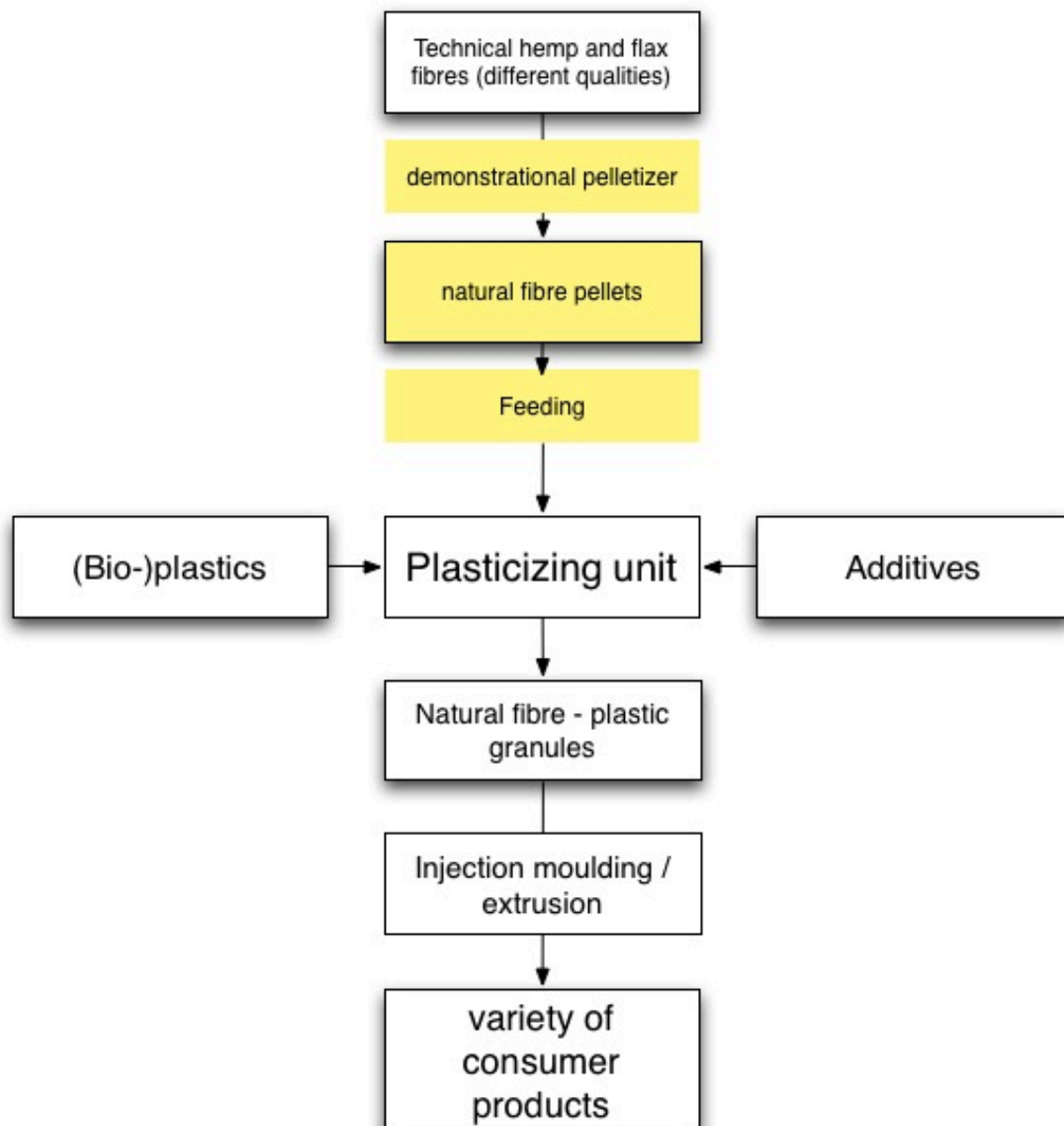
Compounders





Process chain

Not only the technical feasibility but also realistic price evaluation in a close-to-production process were conducted in the project





Problem: Fibre Feeding

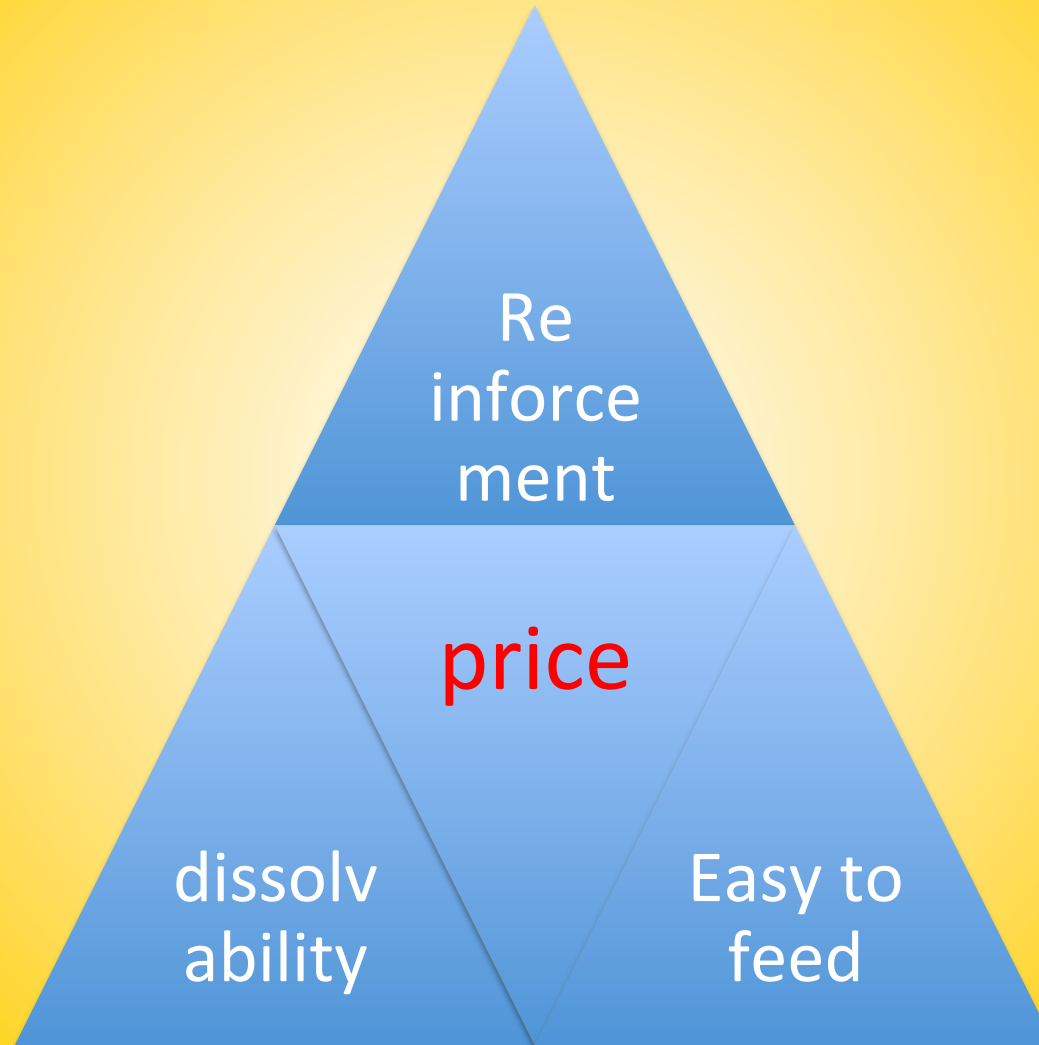
Solution: Softpellets?



Picture: nova 2010



Pellet properties





Pelletizing Hemp Fibres (BaFa)

- Low cost and easy to feed
- Problem is solved by a previous step in the value chain
- Easy to process for the compounder and most importantly easy to dose
- Tests with and without different binders have been conducted



Properties of the „Softpellets“

- Firm enough for stability during storage, transport, drying and feeding
- „Soft“ enough for good dissolving and dispersion in the Compounding/Extrusion process
- Good mechanical reinforcement effect in test specimens and products



Pelletizing Plant

View Pelletizer /
Screening
conveyor

Lean, robust and
cost effective
technology





Pelletizing Plant



1 Bale opener

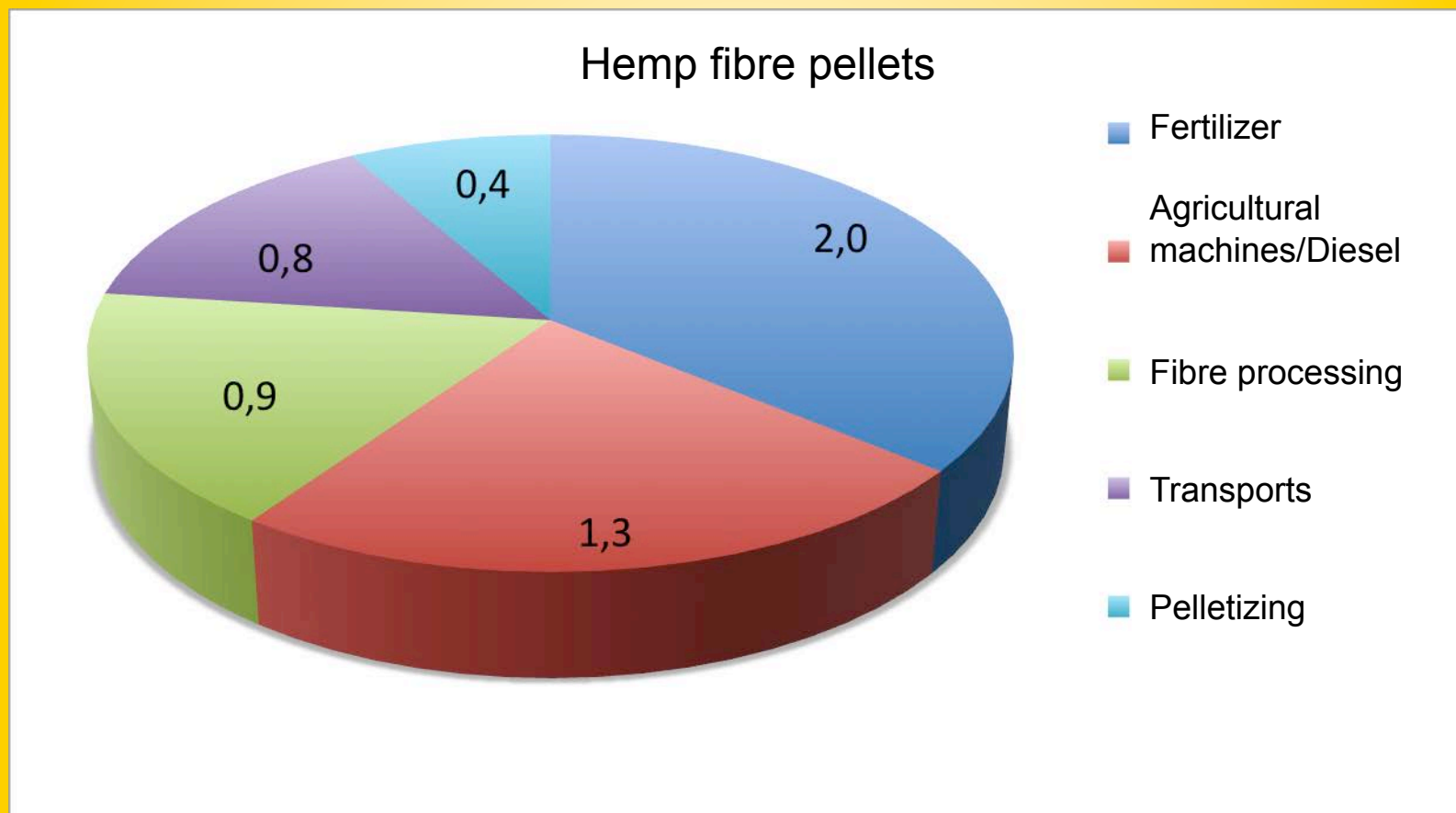
2 Step feeder and
opener for loosening

3 dosing unit with
adjustable discharge



Energy need (CED*) Hemp fibre pellets

Total: 5,4 GJ/t



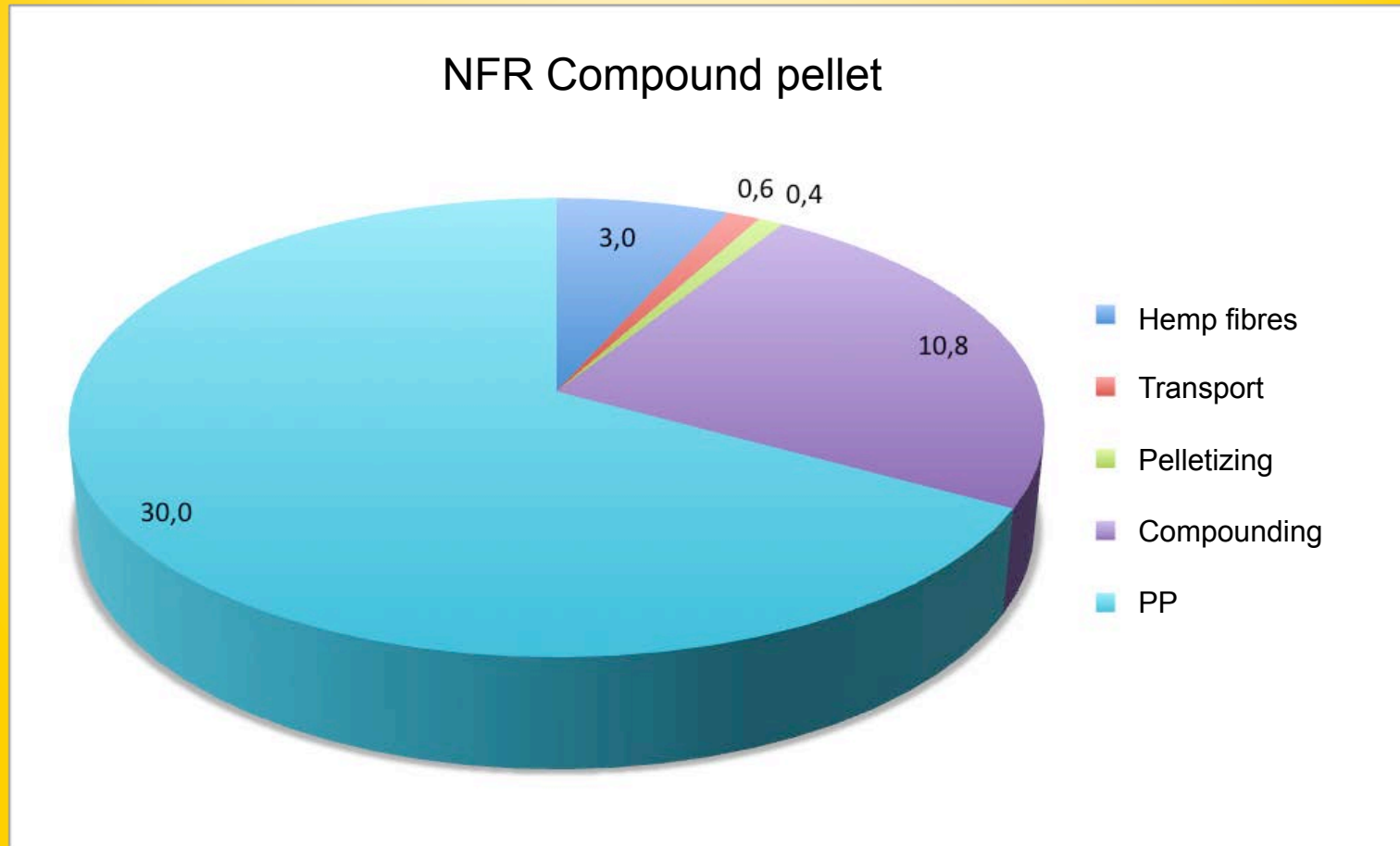
* Cumulated Energy Demand



Energy need (CED) NFP-Compound pellet 60/40

For Extrusion or as Master batch for injection moulding

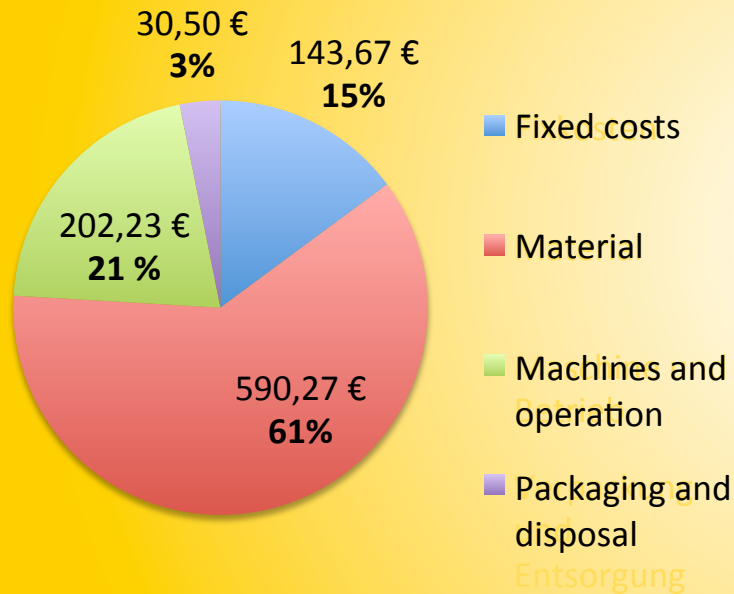
Total: 44,8 GJ/t





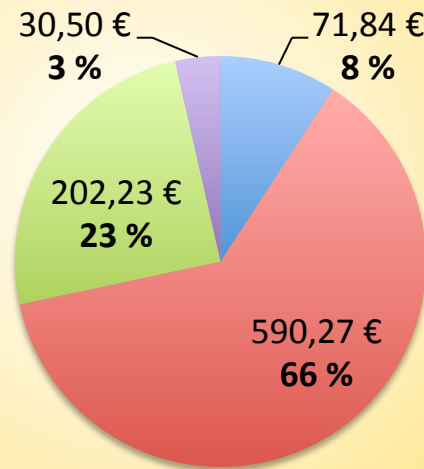
Example BAFA SKF* 100 % - distribution of costs

1-Shift



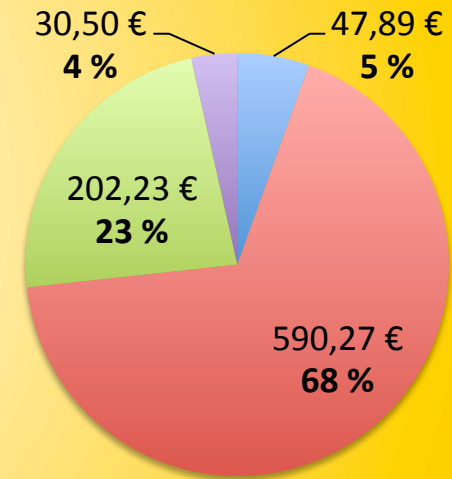
Pellet price 1,06 €/kg

2-Shift



0,98 €/kg

3-Shift



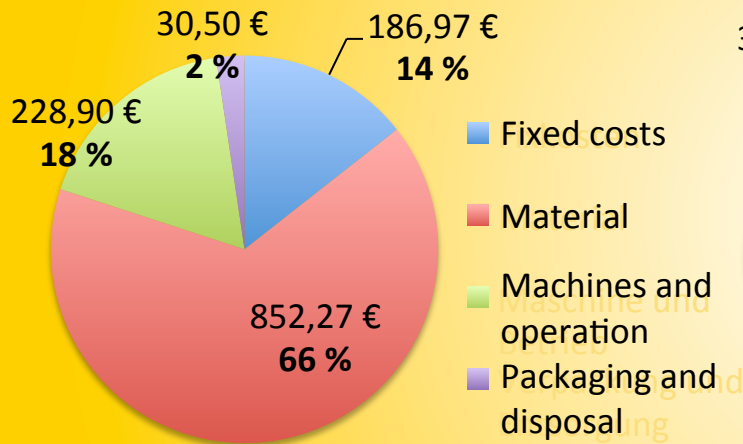
0,96 €/kg

* SKF: Super short fibres



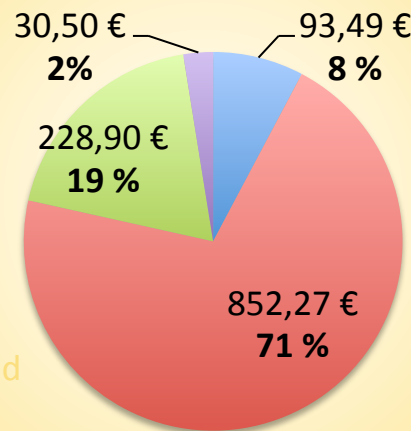
BAFA KF* 60 %, PP 40 % - distribution of costs

1-Shift



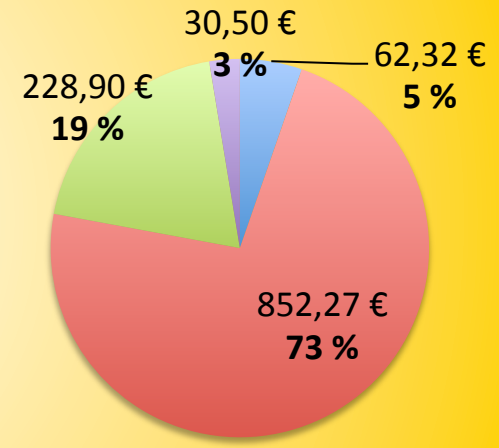
Pellet price: 1,43 €/kg

2-Shift



1,33 €/kg

3-Shift



1,29 €/kg

* KF: Short fibres



Project results

- Hemp fibres are „pelletizable“, tests with other fibres have been successful too; steady feeding of polymers and additives into the pellets was realised successfully.
- semi-automated, industrial pelletizing plant with an output of up to 900 kg/h was designed, put into operation and optimized.
- Gravimetric dosing of the pellets is possible.
- Pre-drying of the natural fibres is simplified.
- Dispersion in the plastic resin and homogenous distribution achievable.



Project results

- Reproducible pellet qualities achieved.
- Granulation of the compound successful.
- Mechanical properties of the test specimens show a satisfying reinforcing effect of the fibres, approaches for improvement were elaborated.
- Pellets were also successfully tested on industrial plants by different interested plastic processors.
- Economy: target price of 1,10 – 1,30 €/kg could be reached.
- Ecology: Low energy need for the pelletizing process in relation to the entire value chain.