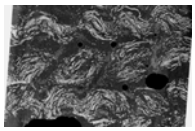
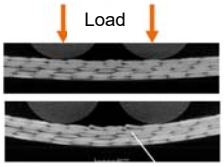
ISSSB 2018 Workshop: Biocomposites for Technical Applications - Life Cycle and Sustainability







In-situ CT analysis (3-point bending)

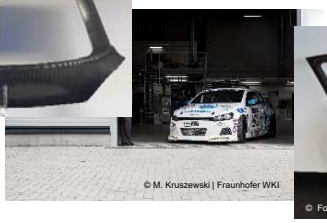






Helicopter cabin CAD model







© Fraunhofer WKI

Fraunhofer WKI

Madina Shamsuyeva



Educational background:

- M. Sc. with major in Chemistry Education from the Middle East Technical University METU, 2010 (Ankara, Turkey)
- M. Sc. with major in Chemistry from the University of Siegen, 2013 (Siegen, Germany)
- PhD at the Technical University of Braunschweig in the field of surface treatment of cellulose fibers (ongoing)

Professional experience and activities:

- Research associate at the Fraunhofer Institute for Wood Research WKI, Application Center HOFZET, since 2014
- Management and implementation of national and international projects in the field of biocomposites
- Practical involvement in various industrial projects on composite development, e.g. by Bayer MaterialScience

© Fraunhofer WKI

Fraunhofer WKI

Hans-Josef Endres

52 years old, married, 2 daughters (23 and 18)

Educational background:

- Dipl.-Ing. graduate of the Ruhr University Bochum, 1985, mechanical engineering, strong focus on material research
- PhD (Dr.-Ing.) received from University of Bochum, 1995



Source: China Hopson

Professional experience and activities:

- 9 years of employment with industrial companies including a position as departmental director at Thyssen-Krupp, overseeing a staff of 230
- **Professor at Hannover University of Applied Sciences & Arts, 1999 ff.**
- **Director of the IfBB - Institute for Bioplastics and Biocomposites, 2011**
- **Head Application Center for Wood Fiber Research, Fraunhofer Wilhelm-Klauditz-Institut WKI, 2012**
- Co-opted Professor at Technical University of Braunschweig, 2016
- Achievements: - engaged in bioplastics and biocomposites research for more than 25 years;
  - established the IfBB - Institute for Bioplastics and Biocomposites as a new institute;
  - established a new Fraunhofer Application Center for Wood Fiber Research;
  - authored various publications and received numerous honors and prizes for his research in bioplastics and biocomposites

© Fraunhofer WKI

Fraunhofer WKI

Outlook

Part I

- Introduction into the IfBB and HOFZET
- Introduction into
  - Biopolymers
  - Biocomposites
  - Bio-hybrid composites
- Ecological issues
  - Land use calculation
  - End of Life
  - LCA

Part II

- Bio-hybrid composites
  - Material development
  - Process & facility development
- Surface treatment of fibers
  - Compatibility in hybrid composites
  - Improvement of specific properties
  - Function integration

© Fraunhofer WKI

Fraunhofer WKI

Outlook

Part I

- Introduction into the IfBB and HOFZET

- Introduction into
  - Biopolymers
  - Biocomposites
  - Biohybridcomposites

- Ecological issues
  - Land use calculation
  - End of Life
  - LCA

© Fraunhofer WKI

Fraunhofer WKI

IfBB – Institute for Bioplastics and Biocomposites – Hanover

IfBB Institute for Bioplastics and Biocomposites

- Officially founded as an institute of the Hanover University of Applied Sciences and Arts in 2011 (as consequence of continuously increasing research in the field of bioplastics and biocomposites)
- Approx. 30 employees, 10 PhDs
- Annual turnover approx. € 5 million $ CAD
- Head of Institute: Prof. Dr.-Ing. Hans-Josef Endres
- Wide, large-scale research facilities for plastics technology, material research and testing
- Numerous projects in the field bioplastics and biocomposites, carried out in close collaboration with industry



Source: David Carreno Hansen



Source: David Carreno Hansen



Source: China Hopson

IfBB research

IfBB
Institute for Bioplastics and Biocomposites


Source: David Carreno Hansen


Source: David Carreno Hansen


Source: David Carreno Hansen


Source: David Carreno Hansen

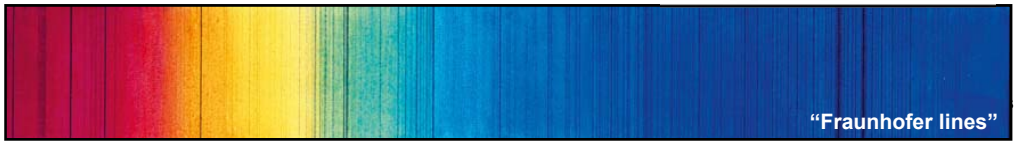

Source: David Carreno Hansen

Development of Materials | **Processing** | **Material testing** | **Upscaling** | **Recycling, Ecological evaluations**

Fraunhofer-Gesellschaft

- Founded in 1949
- Today
  - The largest organization for applied research in Europe
  - 69 institutes and research units
  - More than 24.500 staff



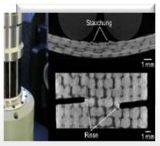


© Fraunhofer WKI

Fraunhofer WKI

Research focus of the HOFZET




Material development	Material processing	Manufacture of construction parts	Material and part analysis	End of Life Eco balance
Plastics	Injection molding	Autoclave	CT	Recycling
Organic sheets	Compounding / extrusion	Hot press	SEM	Pyrolysis
Hybrid fabrics	3D printing	Fiber-spraying	Mechanical testing	LCA
…	…	…	…	…

© Fraunhofer WKI

Fraunhofer WKI

Outlook

Part I

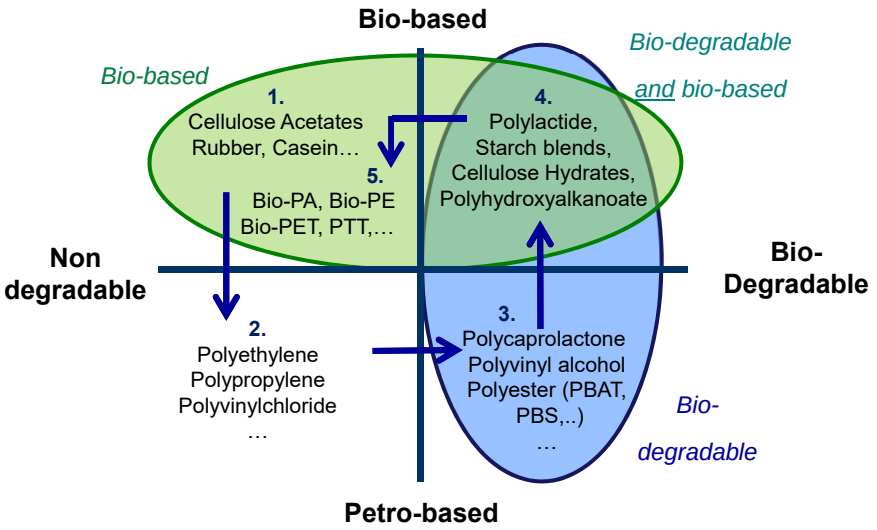
- Introduction into the IfBB and HOFZET
- Introduction into
  - Biopolymers
  - Biocomposites
  - Biohybridcomposites
- Ecological issues
  - Land use calculation
  - End of Life
  - LCA

© Fraunhofer WKI

Fraunhofer WKI

Biopolymers

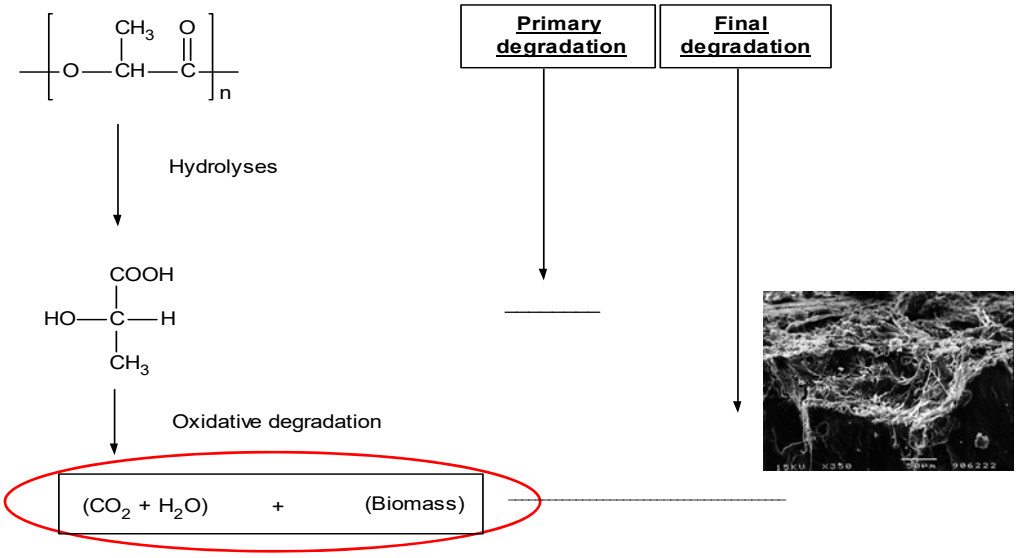
IfBB Institute for Bioplastics and Biocomposites



Source: H.-J. Endres, A. Siebert-Raths; Engineering Biopolymers, Carl Hanser-Verlag, 2011

Biodegradability

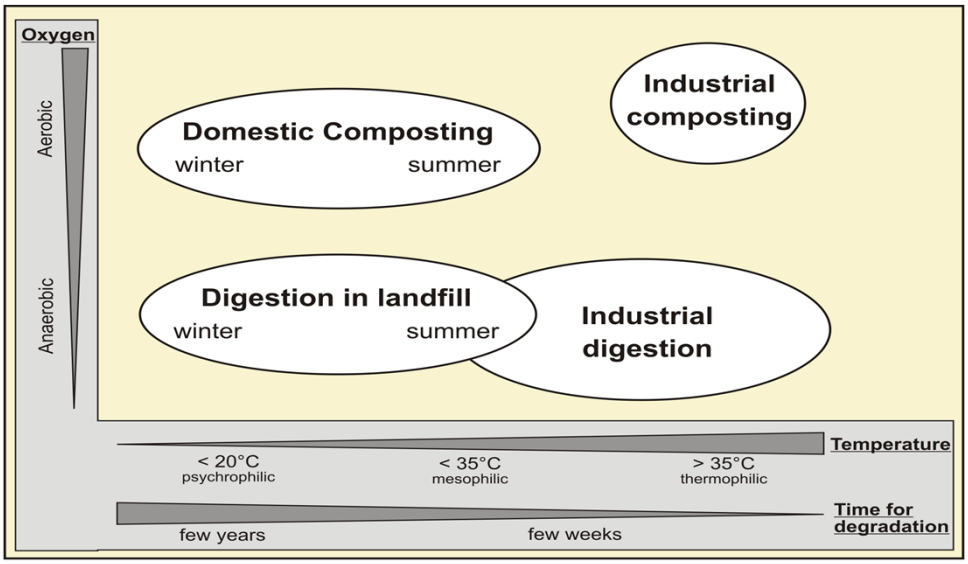
IfBB Institute for Bioplastics and Biocomposites



H.-J. Endres, A. Siebert-Raths, Engineering Biopolymers, Carl Hanser Verlag 2011

Degradation principles

IfBB Institute for Bioplastics and Biocomposites

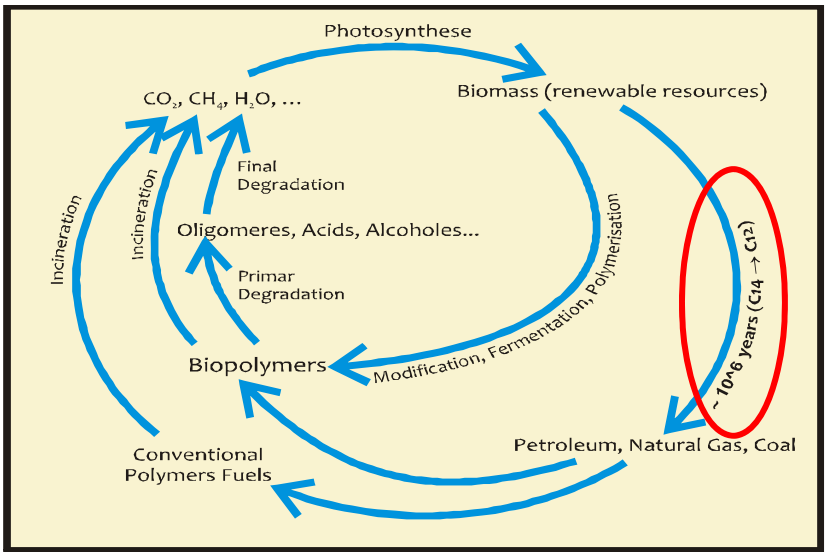


H.-J. Endres, A. Siebert-Raths, Engineering Biopolymers, Carl Hanser Verlag 2011

Source: H.-J. Endres, A. Siebert-Raths; Engineering Bioplymers, Carl Hanser-Verlag, 2011

What is „biobased“

IfBB Institute for Bioplastics and Biocomposites



Quelle: H.-J. Endres, A. Siebert-Raths; Engineering Biopolymers, Carl Hanser-Verlag, 2011

Certification of biobased content

IfBB Institute for Bioplastics and Biocomposites



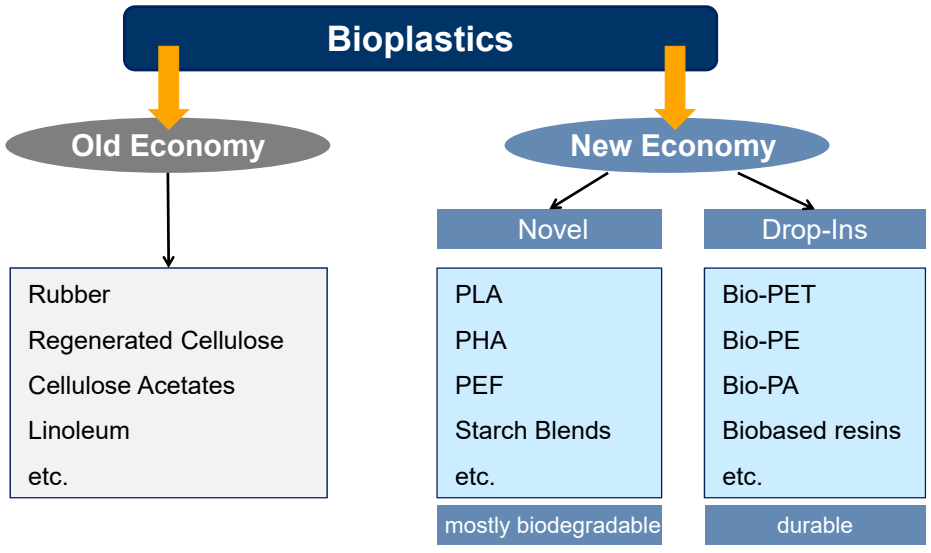
DIN CERTCO



Vincotte

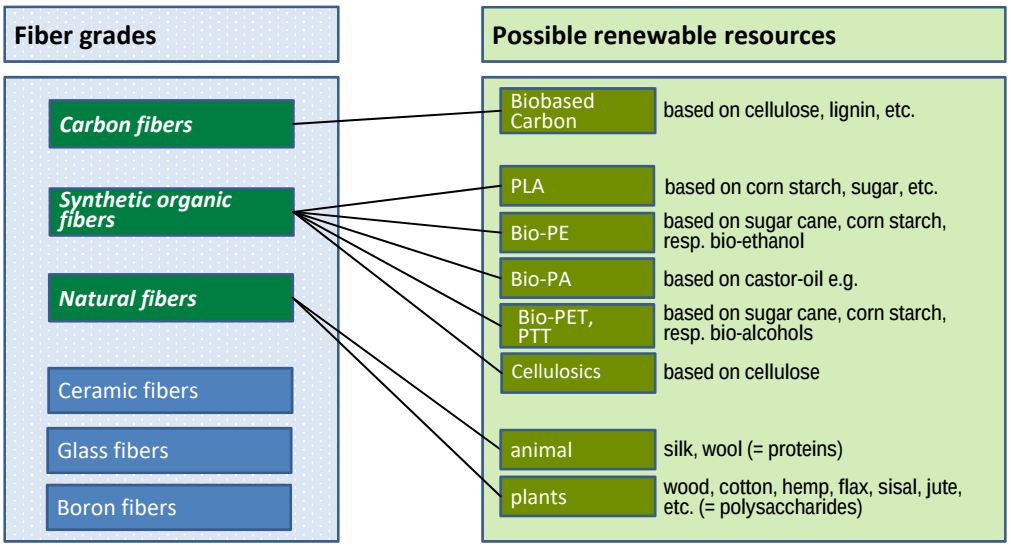
Old and New Economy Bioplastics

IfBB Institute for Bioplastics and Biocomposites



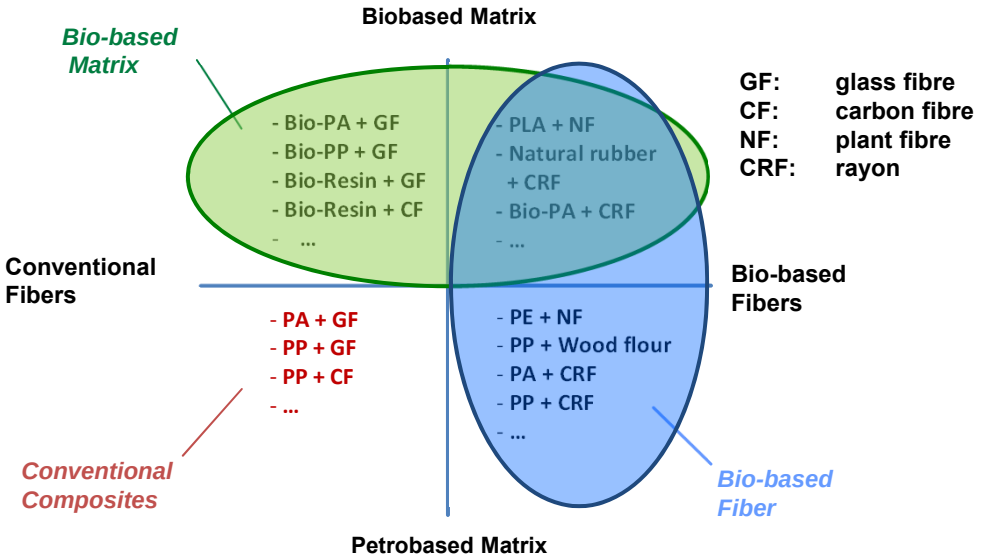
Source: H.-J. Endres, unpublished

Biobased Fibres



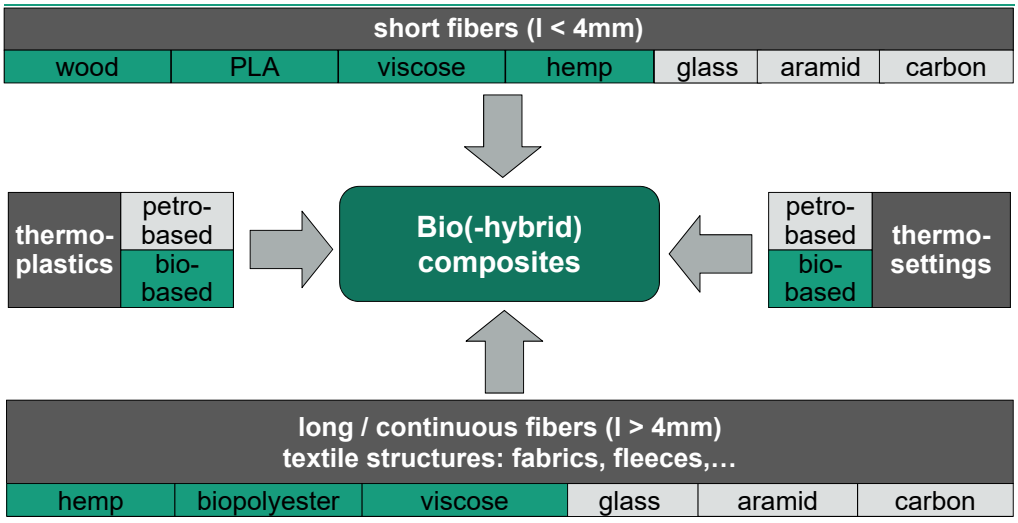
Source: H.-J. Endres, T. Koplin, C. Habermann, Technology and Nature Combined, Kunststoffe International , 2012

Biocomposites



Source: H.-J. Endres, T. Koplin, C. Habermann, Technology and Nature Combined, Kunststoffe International , 2012

Bio(-hybrid) composites



© Fraunhofer WKI

Fraunhofer WKI

Outlook

Part I

- Introduction into the IfBB and HOFZET
- Introduction into
  - Biopolymers
  - Biocomposites
  - Biohybridcomposites
- Ecological issues
  - Land use calculation
  - End of Life
  - LCA

© Fraunhofer WKI

Fraunhofer WKI

What is the yield

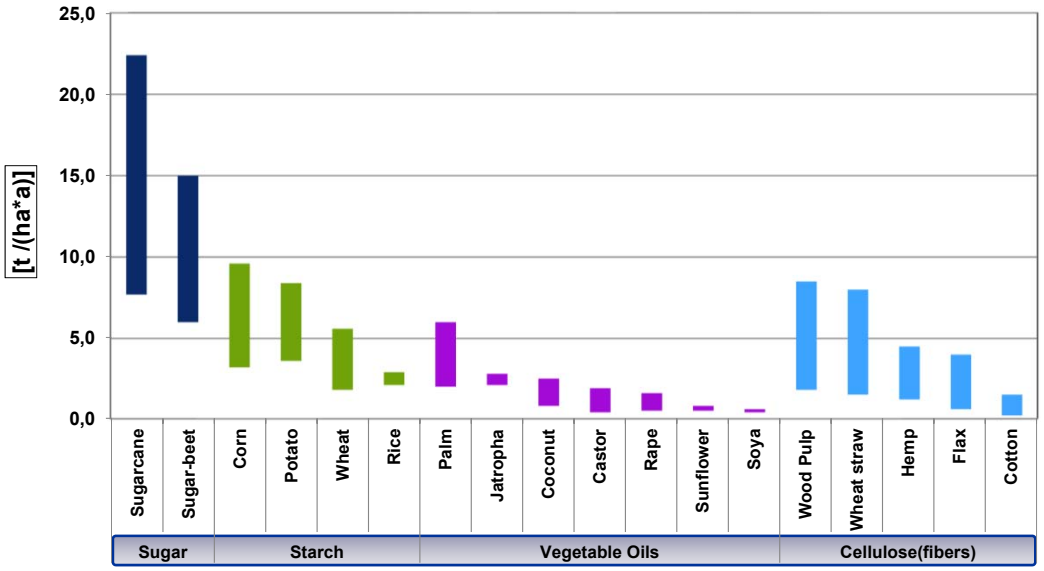
IfBB Institute for Bioplastics and Biocomposites

Feedstock	Crop	Raw material	Global mean yield * (Crop)	Average content of raw material	Resulting amount (raw material)
Calculations			->	x ->	=
Sugar cane	Sugar cane (without cane tops)	fermt. Sugar	72.7 t/ha	13 %	9.46 t sugar/ha
Sugar beet	Beet (without leaves)	fermt. Sugar	57.8 t/ha	16 %	9.24 t sugar/ha
Corn	Maize kernel	Starch	6.7 t/ha	70 %	4.69 t starch/ha
Potatoes	Potato tuber	Starch	22.2 t/ha	18 %	4.0 t starch/ha
Wheat	Wheat grains	Starch	3.74 t/ha	46 %	1.72 t starch/ha
Wood	Standing timber, residual wood	Cellulose	1.64 t atro/ha	40 %	0.66 t cellulose/ ha
Castor oil plant	Castor bean (seeds)	Castor oil	1.28 t seeds/ha (given one harvest per year)	40 %	0.51 t oil/ha (given one harvest per year)

* Global mean yield over the last 10 years, weighted by respective production amount (based on FAOSTAT 2005 - 2014).

Yields of renewable raw materials

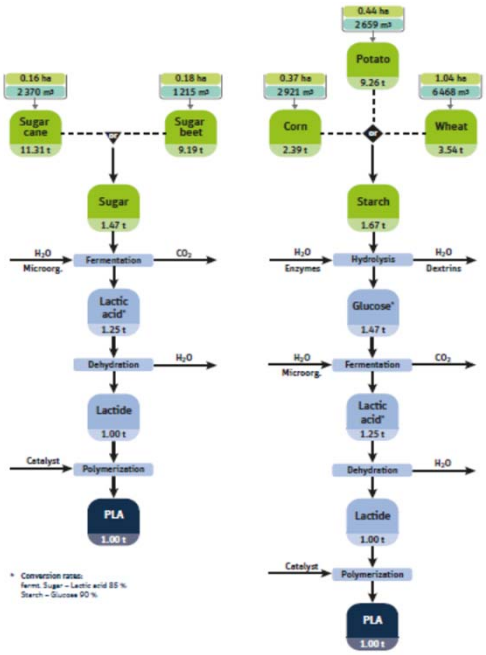
IfBB Institute for Bioplastics and Biocomposites



Source: Hans-Josef Endres, Andrea Siebert-Raths; Engineering Biopolymers, Carl Hanser-Verlag, 2011

Processing Routes for Feedstock Calculation

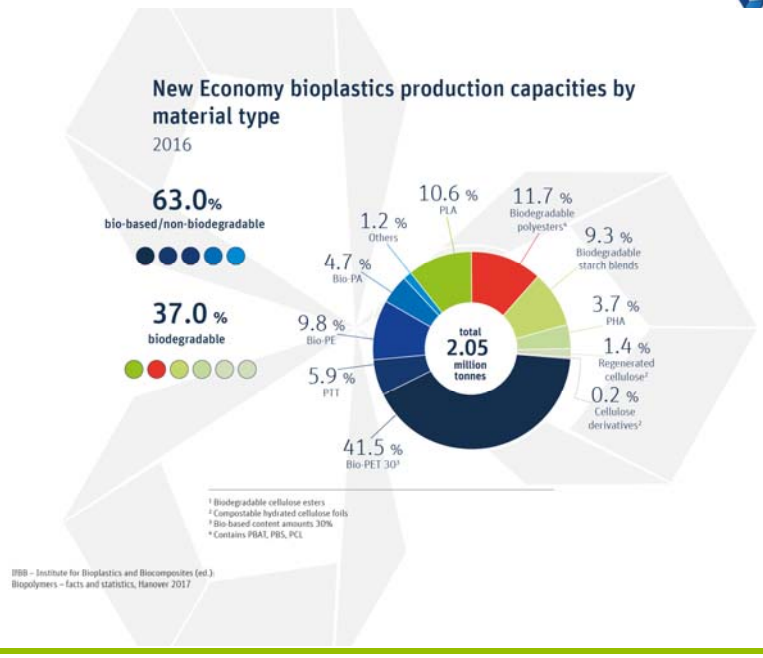
IfBB Institute for Bioplastics and Biocomposites



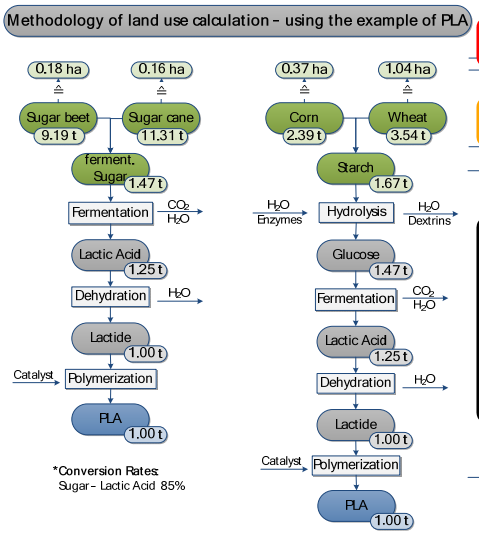
Source: IfBB, www.downloads.ifbb-hannover.de

Production cpacities

IfBB Institute for Bioplastics and Biocomposites



From capacities to land use: Basic methodology



Step 3

Multiplication of production capacities by output data of the corresponding process routes („bottom-up approach")

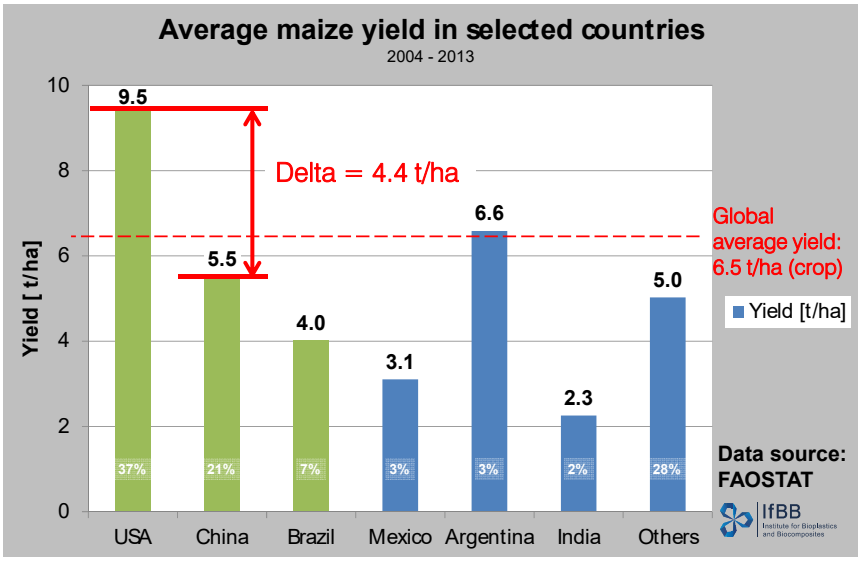
Step 2

Calculation of land use data on basis of yield data from FAO statistics (global average over the past 10 years)

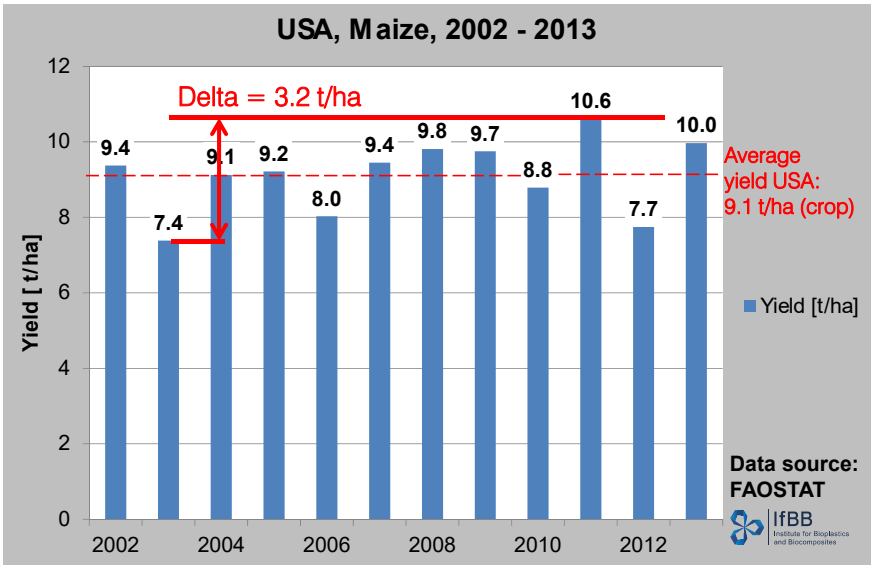
Step 1

- Plotting the manufacturing steps involved from the raw material to the finished product, including input-output streams
- Calculating the mass flow by a molar method based on the chemical process
- Incorporation of known factors and conversion rates
- Agreeing upon the routes so established with polymer manufacturers and industry as far as possible

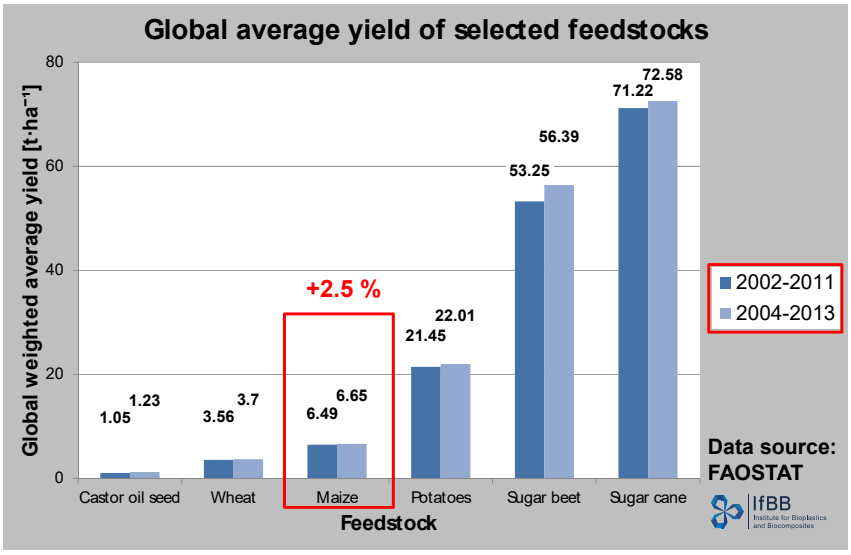
Critical Impact Factor: Feedstock yield - Regional versus global



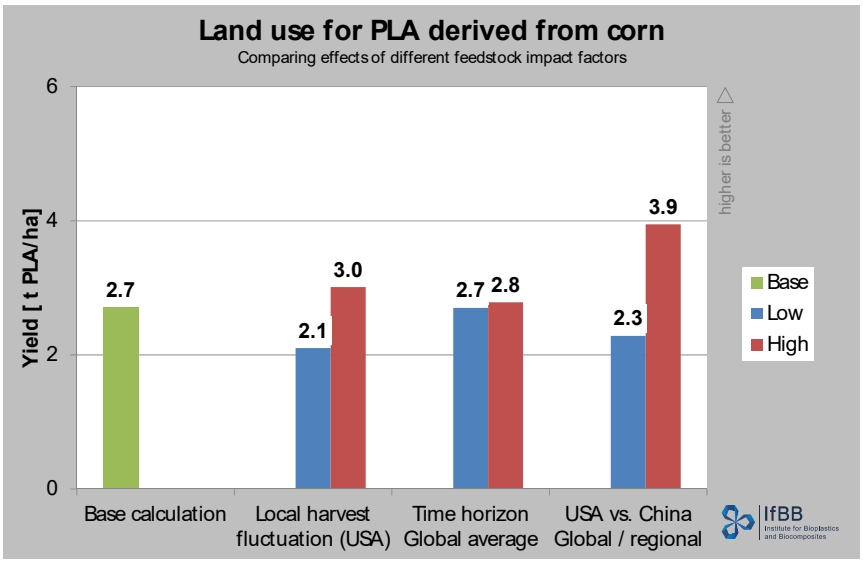
Critical Impact Factor: Feedstock yield - Natural climatic fluctuation



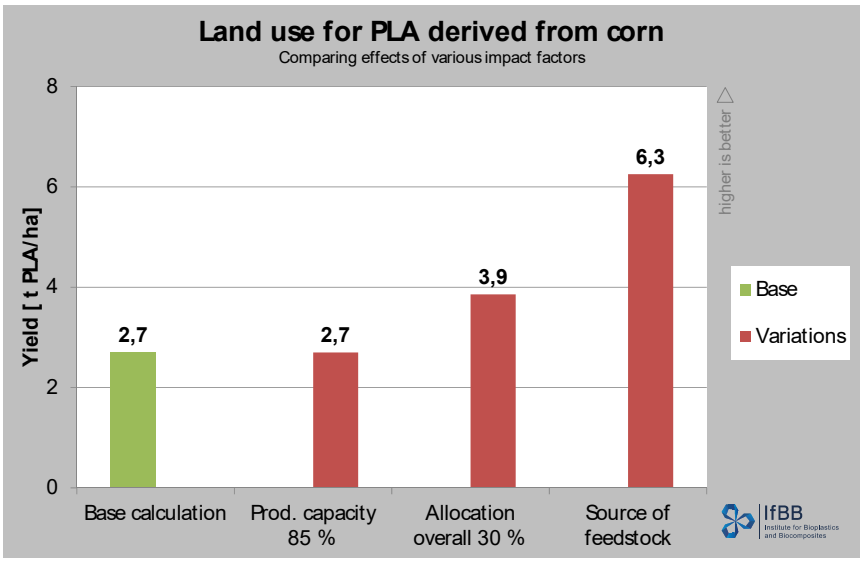
Critical Impact Factor: Crop yield - Shifting average time horizon



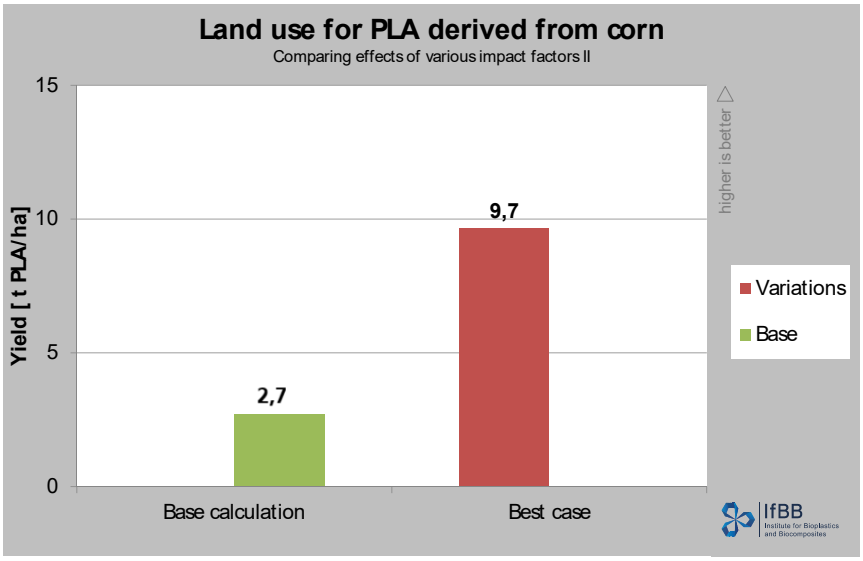
Comparison of sensitivity results - Feedstock corn



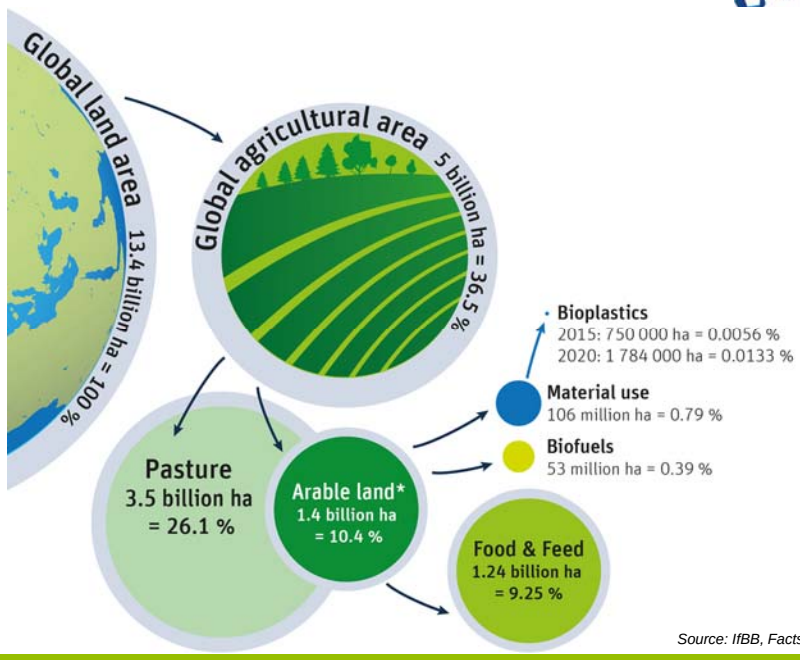
Comparison of sensitivity results - Variable impact factors



Comparison of sensitivity results - Base and best scenario



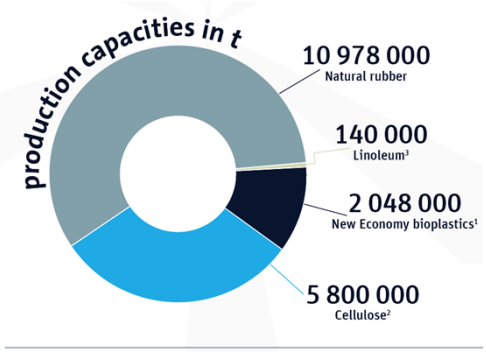
Land Use of New Economy Bioplastics

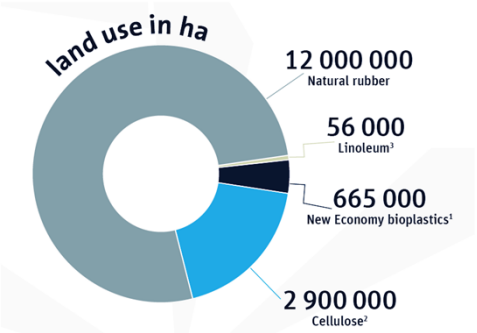


Source: IfBB, Facts and statitics, 2016

Old and New Economy Bioplastics (2014)

IfBB Institute for Bioplastics and Biocomposites





¹ PLA, PHA, PTT, PBAT, Starch blends, Drop-Ins (Bio-PE, Bio-PET, Bio-PA) and other
² Material use excl. paper industry
³ Calculations include linseed oil only

Source: IfBB, Facts and statitics, 2016

Outlook

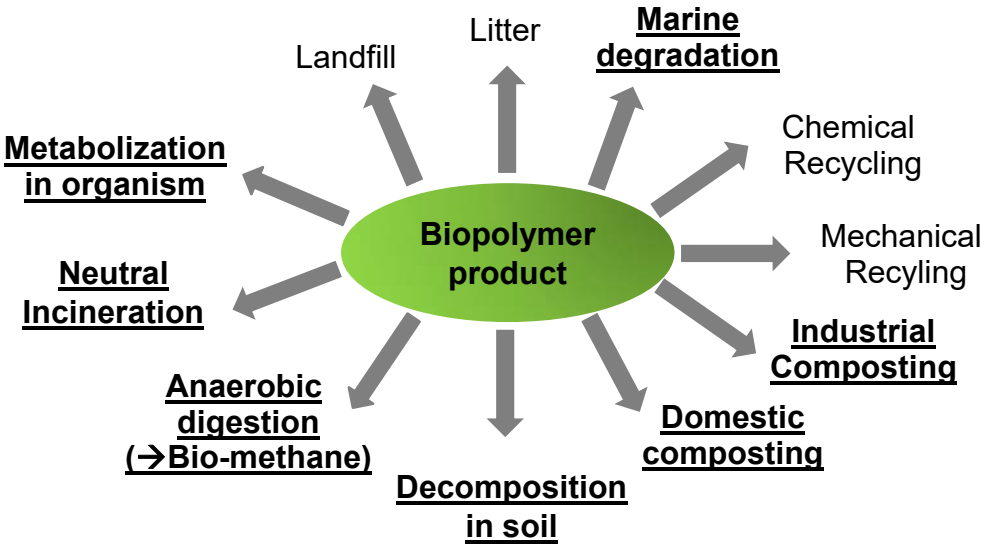
Part I

- Introduction into the IfBB and HOFZET
- Introduction into
  - Biopolymers
  - Biocomposites
  - Biohybridcomposites
- Ecological issues
  - Land use calculation
  - End of Life
  - LCA

© Fraunhofer WKI

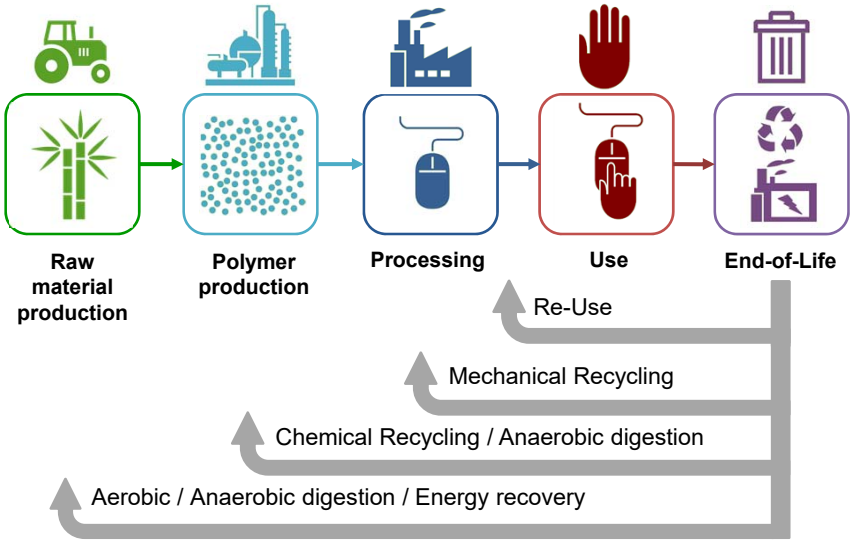
Fraunhofer WKI

End-of-Life Options of Biopolymers



Source: H.-J. Endres, A. Siebert, A.-S. Kitzler
Biopolymers – a discussion on end of life options
Bioplastics Magazine 01/08

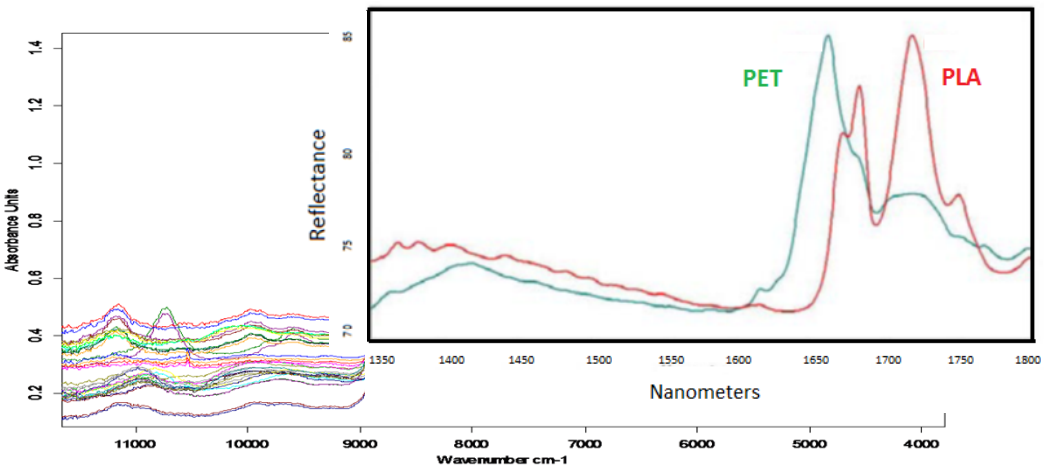
Bio-based plastics and Circular economy



Quelle: S. Spierling, H.-J. Endres, et.al. Bio-based Plastics – A Building Block for the Circular Economy
25th CIRP Life Cycle Engineering (LCE) Conference, 30 April – 2 May 2018, Copenhagen, Denmark

Identifiability in waste streams using NIR

IfBB Institute for Bioplastics and Biocomposites

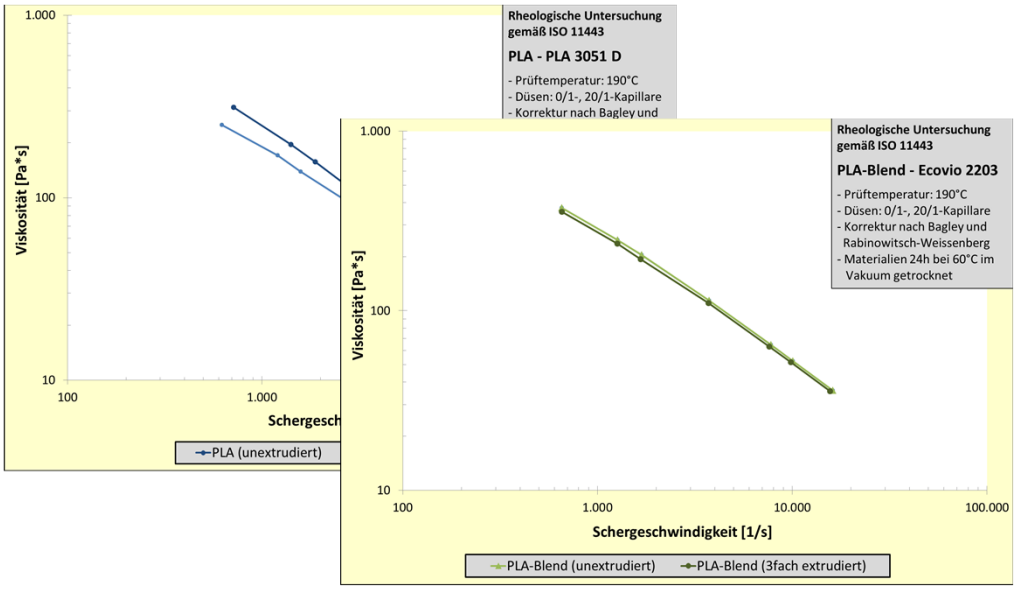


Proben 1-18: Biopolymere
Aufnahme der Spektren am 03.06.2008
Gerät: NIR Bruker N/22
Meßexperiment: LUFA-Pulver-ulbricht.xpm
im Becherglas als Zweifachmessung

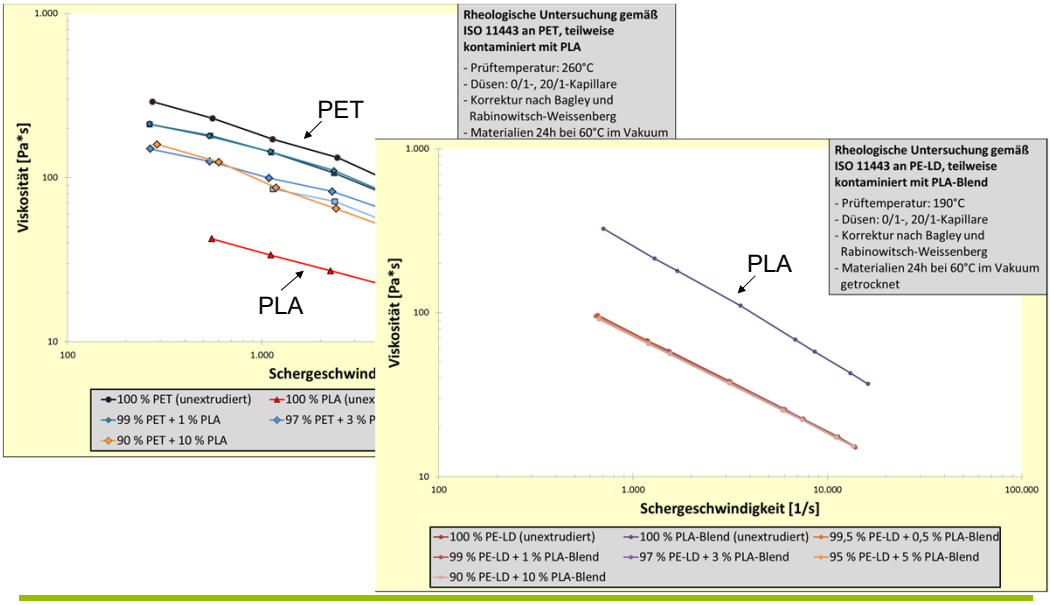
H.-J. Endres, A. Siebert-Raths, Engineering Biopolymers, Carl Hanser Verlag 2011

Influence of multiple thermo-mechanical stress on viscosity (post production scenario)

IfBB Institute for Bioplastics and Biocomposites



Influence of multiple thermo-mechanical stress on viscosity (post consumer scenario)



Bioplastics as renewable energy source

Theoretical calculation of the calorific value (Boie):

$$H_{waf} = 34{,}8\varphi_C + 93{,}9\varphi_H - 10{,}8\varphi_O$$

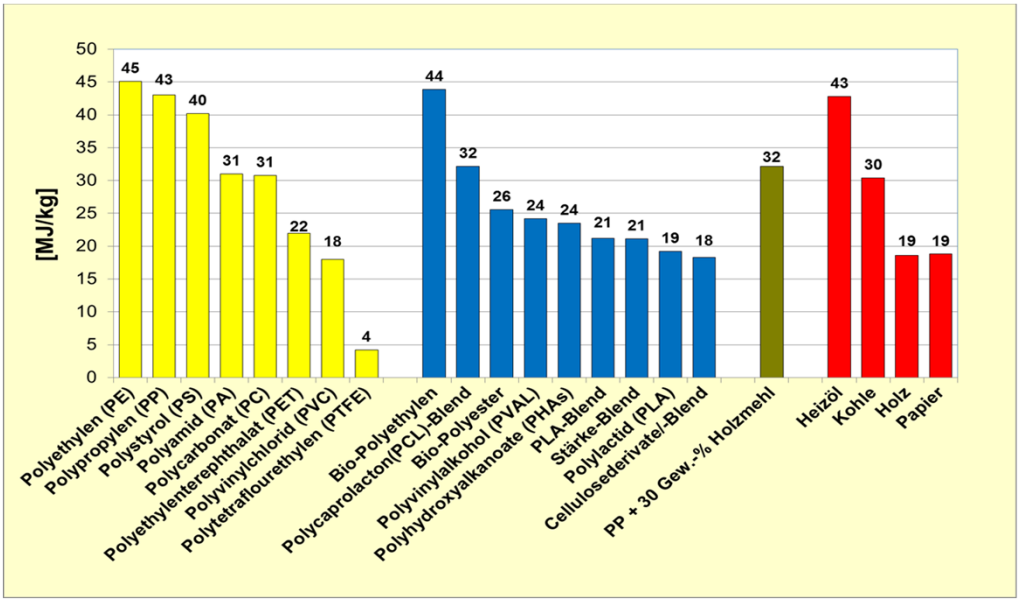
Calculated values:

- PLA: 17,9 MJ/kg
- Bio-PE: 43,3 MJ/kg
- Celluloseester: 17,5 MJ/kg

Measured values:

- Corresponding to calculated values

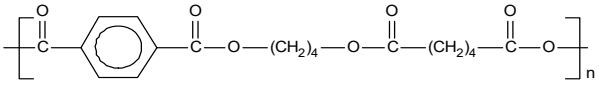
Calorific values of different (bio)plastics

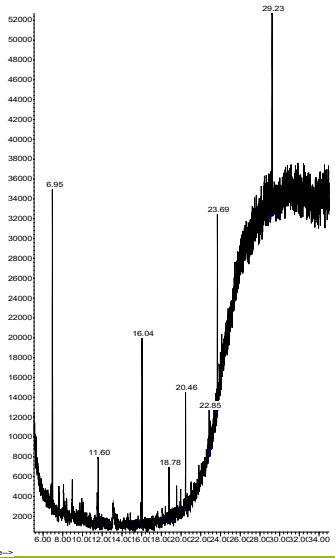


H.-J. Endres, A. Siebert-Raths, Engineering Biopolymers, Carl Hanser Verlag 2011

Emission of biopolymers by Incineration

e.g. PBAT
(Polybutylenadiapatterephthalate)





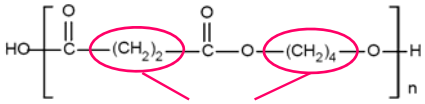
H.-J. Endres, C. Laußmann, A.-S. Kitzler: 04/2009

Metabolisation of biopolymers into bio-gas

- Calculated values :
  PLA: 305,5 l
  PBS: 340,9 l
  PVAL: 333,1 l

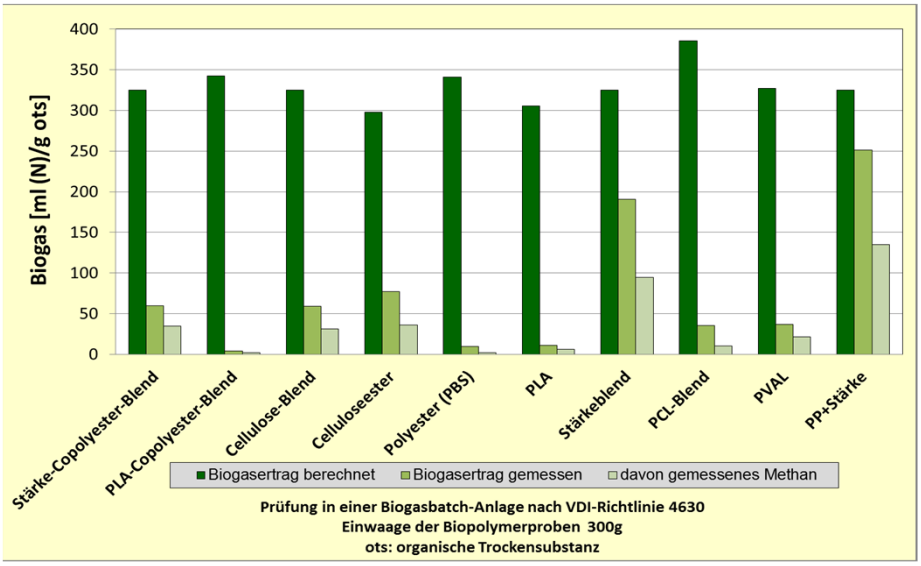
- measured values:
  PLA: 10,71 l
  PBS: 9,79 l
  PVAL: 37,09 l

Low metabolisation rate e.g. PBS:



Monomer unit

Transformation to biogas resp. biobased methan



Quelle: A.S. Kitzler, H.-J. Endres, M. Nelles, Fachtagung „Biokunststoffe in Verwertung und Recycling", Dresden, 03. - 04. Dezember 2012

HOCHSCHULE
HANNOVER
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS
–
Fakultät II
Maschinenbau und
Bioverfahrenstechnik

IfBB
Institute for Bioplastics
and Biocomposites



Biodegradable plastics – part or solution of the marine litter problem?

Prof. Dr.-Ing. Hans-Josef Endres, Dipl.-Ing. Simon McGowan

Research activities for marine biodegradable plastics

IfBB
Institute for Bioplastics
and Biocomposites

- The IfBB is engaged in fundamental research into the subject of the (marine) degradability of biodegradable plastics

Water Conditions
- Temperature
- Composition
- Biological activity

Polymer
- Type / Grade
- Crystallinity
- Surface



Functional filler
- Soluble / Insoluble
- Metabolizable?
- Biodegradable?

Primary degradation and final degradation

Influence of light irradiation?

Influence of marine life?

Influence of mech. stress?

Outlook

Part I

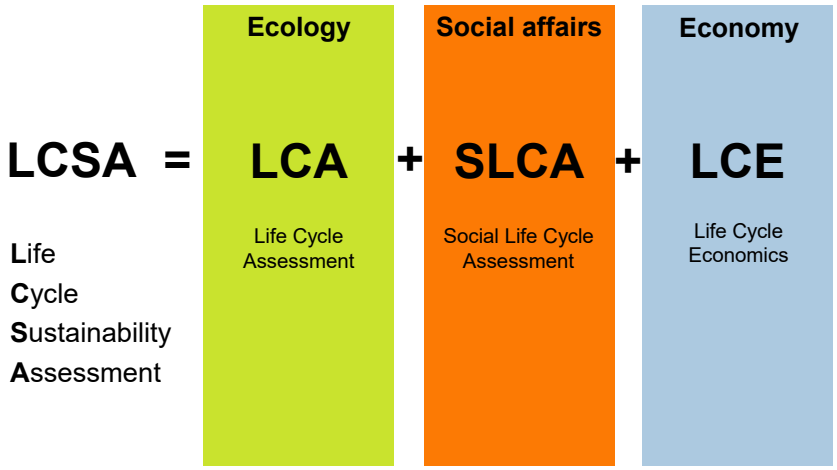
- Introduction into the IfBB and HOFZET
- Introduction into
  - Biopolymers
  - Biocomposites
  - Biohybridcomposites
- Ecological issues
  - Land use calculation
  - End of Life
  - LCA

© Fraunhofer WKI

Fraunhofer WKI

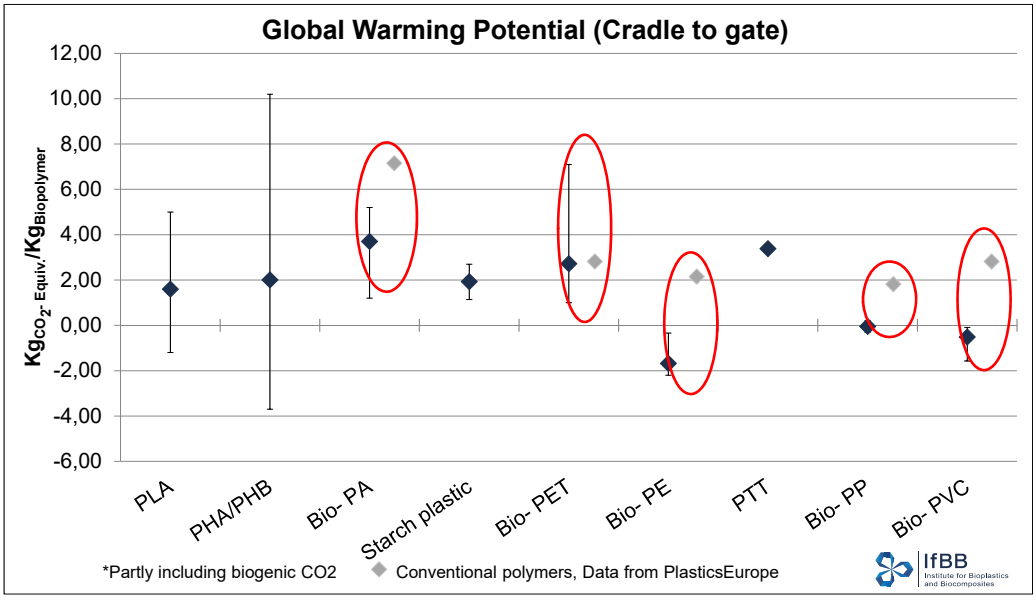
How to measure sustainability?

IfBB Institute for Bioplastics and Biocomposites



Quelle: BiNa 2017

GWP of Biopolymers versus conventional plastics



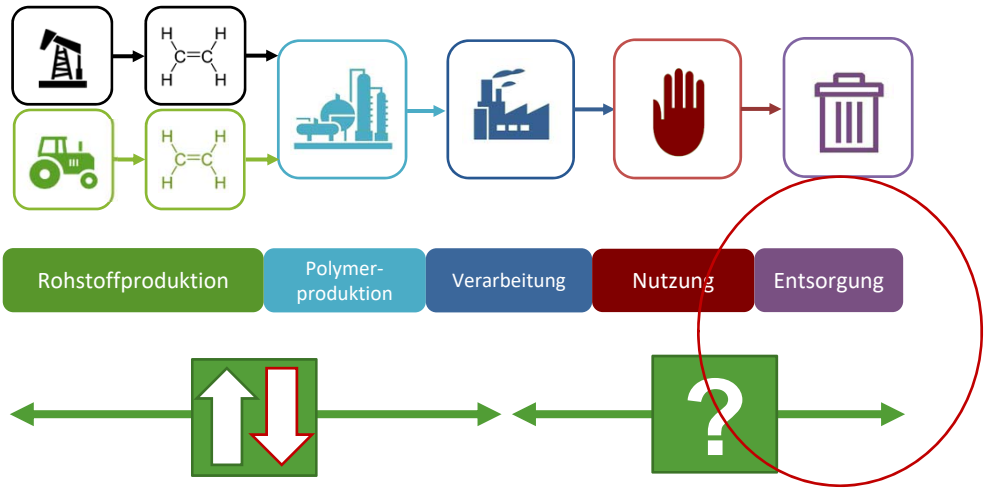
Tendencies of LCA impact categories

Impact category		Reason on the part of Biopolymers
Global Warming Potential	↗	CO_2-uptake
Energy demand	↗	Often in correlation with GWP
Abiotic Depletion Potential	↗	Bio-based
Humantox	↗	Tendency advantage due to savings in fossil energy less combustion processes
Ecotox	↗↘	No tendency, very specific, savings in conventional substance releases vs. sub. from pesticides (field technique)
Photosmog Potential	↗↘	No tendency, very specific, savings in use of conv. energy processes and substances vs. harvesting proc. (burning)
Acidification Potential	↘	Tendency disadvantage, if agrarian products are used (fertilizers) and especially with harvest burnings
Eutrophication Potential	↘	Tendency disadvantage, if agrarian products are used (fertilizers) and especially with harvest burnings
Land use	↘	Agricultural land for biomass production needed
Water use	↘	Additionally to process water, also cultivation water needed

2014

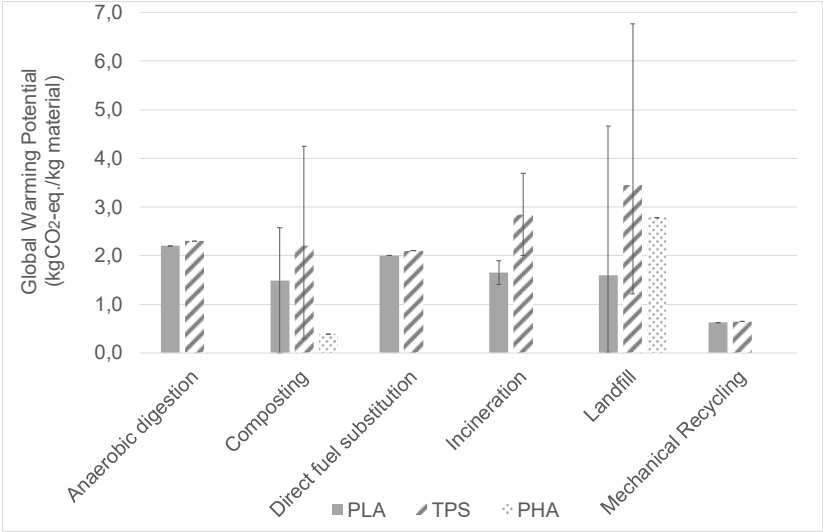
Source: IfBB / PE INTERNATIONAL 2014

End-of Life Scenario has a significant impact on LCA results, in particular for short-lived products



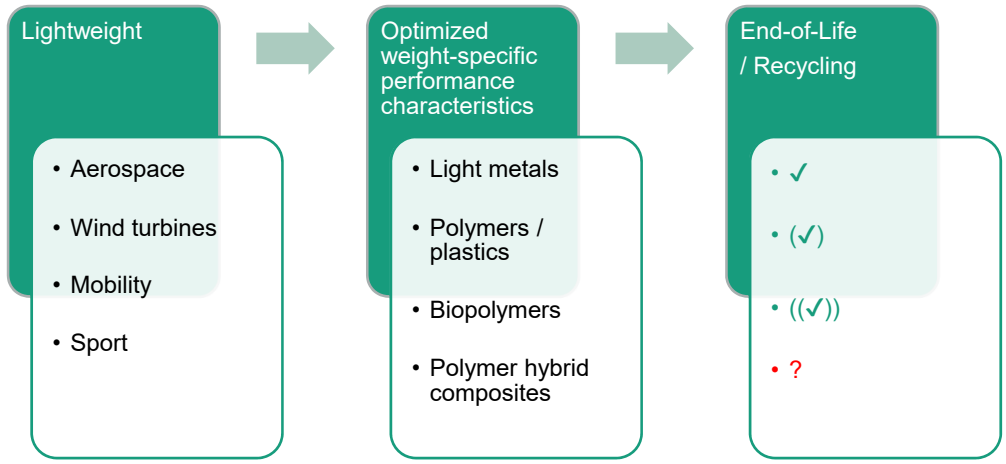
Quelle: BiNa 2017

GWP in case of variable EoL scenarios for PLA, PHA and TPS



Source: Sebastian Spierling, H.-J. Endres et.al., Bio-based Plastics – A Building Block for the Circular Economy? CIRP 2018 , 01.05.2018

Sustainable End-of-Life or better New-Life Concepts as a challenge for (Biohybrid-)Composites



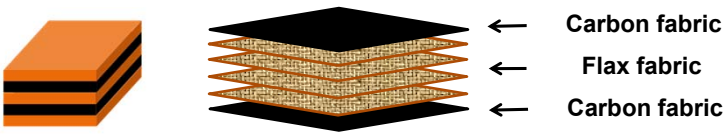
Source: H.-J. Endres, WKI

© Fraunhofer WKI

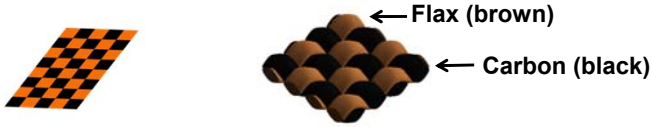
Fraunhofer WKI

Hybrid Structures – Fabric Layer Combination vs. Yarn Combinations

Interlayer (e.g. stacking)

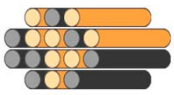


Intralayer (e.g. co-weaving)



© Fraunhofer WKI

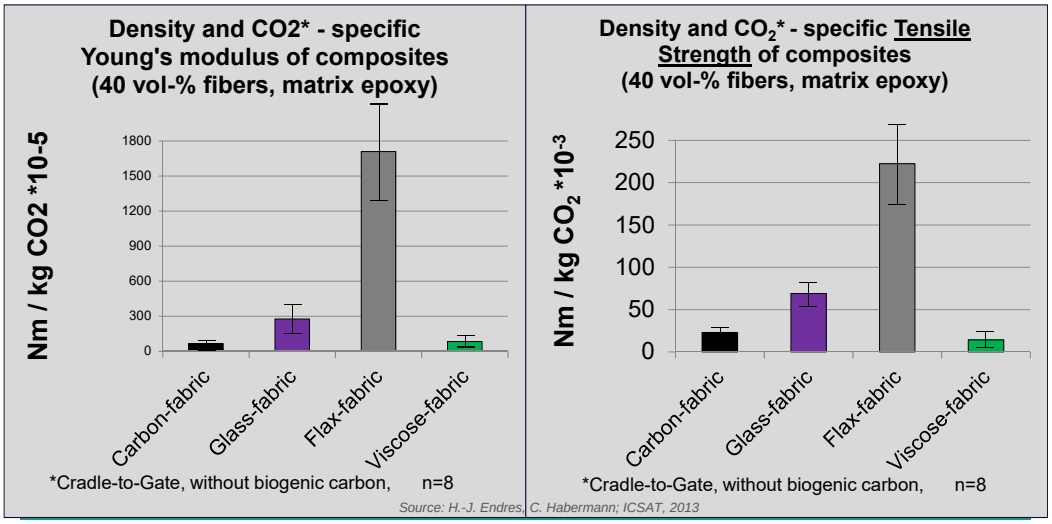
Intrayarn (e.g. commingling)



© Fraunhofer WKI

Fraunhofer WKI

GWP specific mechanical properties



Source: H.-J. Endres, C. Habermann; ICSAT, 2013

© Fraunhofer WKI

Fraunhofer WKI

Selected projects: Next generation Bio-Hybrid-Car



Source: Hans-Josef Endres

© Fraunhofer WKI

Fraunhofer WKI

Contact

Prof. Dr.-Ing. Hans-Josef Endres
Head of the Application Center for Wood Fiber Research
Fraunhofer-Institut für Holzforschung -Wilhelm-Klauditz-Institut WKI

Heisterbergallee 10A
D- 30453 Hanover

Tel 0049 (0) 5 11 / 9296 – 22 68
Fax 0049 (0) 5 11 / 9296 – 99 22 12
Mail hans-josef.endres@wki-fraunhofer.de

Fraunhofer WKI

www.wki.fraunhofer.de

Prof. Dr.-Ing. Hans-Josef Endres
Head of the IfBB
IfBB - Institute for Bioplastics and Biocomposites

Hanover University of Applied Sciences and Arts
Heisterbergallee 10A
D- 30453 Hanover

Tel 0049 (0) 5 11 / 9296 – 22 68
Fax 0049 (0) 5 11 / 9296 – 99 22 68
Mail hans-josef.endres@hs-hannover.de

IfBB Institute for Bioplastics and Biocomposites

www.ifbb-hannover.de

© Fraunhofer WKI

Fraunhofer WKI