# SUGAR BASED CHEMISTRY

2015


# ABOUT AVA BIOCHEM

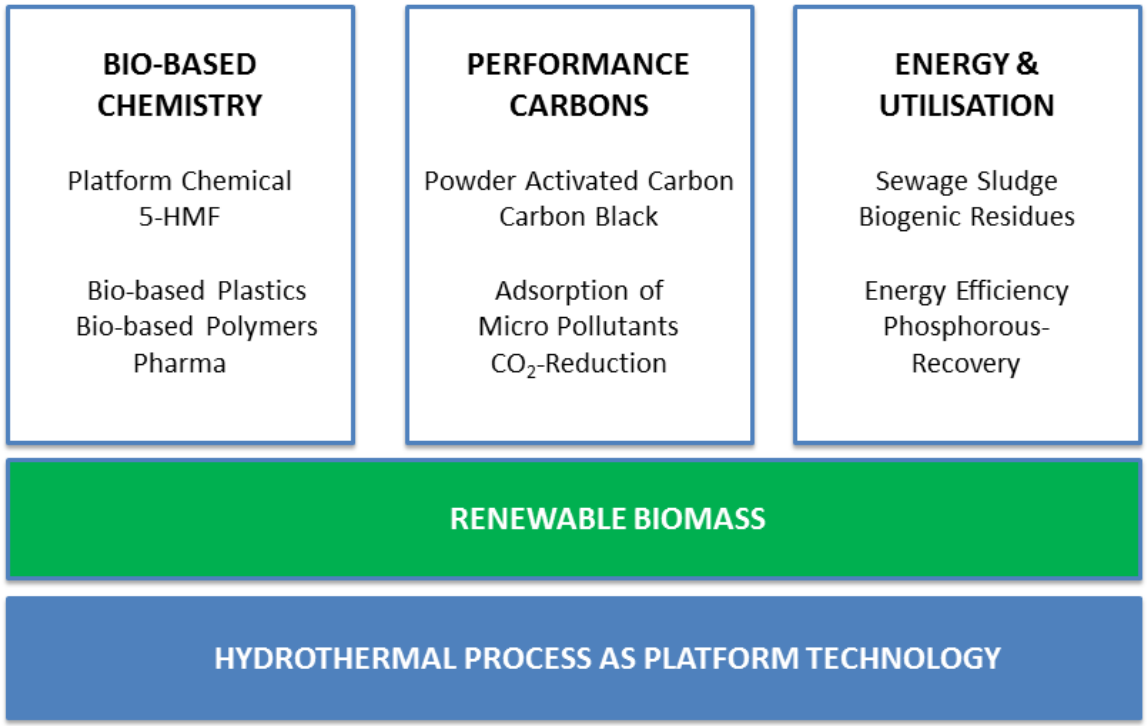
- Founded: 2012
- Subsidiary of AVA-CO2 Switzerland Ltd. – founded in 2009

- 100% privately owned
- AVA Group has 39 employees
- Core technology: Hydrothermal Treatment Process (HTP)

  - AVA Biochem CH-Muttenz
    - Biochem-1 Plant for 5-HMF (2014)
  - AVA-CO2 Research GmbH DE-Karlsruhe
    - HTC-0 Plant for “Waste Biomass to Energy” (2010)

- Core technology: Hydro Thermal Process (HTP)
- Process takes place in aqueous solution (water as solvent)
- Fully scalable technology: bulk production within reach
- 5-HMF in crystalline form or in aqueous solution in various purities available today

# AVA-CO2 THREE PILLAR STRATEGY



# HISTORY – HTC Technology

**1931**

**Nobel Prize**
**Mr. Bergius**

**1997**

Kyoto
Protocol

**2010**

**HTC-0**

Visit of the German Federal
Environmental Minister

**2012**

EU-Projects:
X-Gate & BioBoost

**2014**

Phosphorous recovery
Activated carbon

**1979**

2. Oil crisis

**2009**

**Founding of AVA-CO2;**

**Co-operation KIT**

**2011**

Patent applications

ZHAW/BAFU
Study I

**2013**

HTC-Study
Senate Berlin

ZHAW/BAFU
Study II

**2015**

First commercial
HTC-Projects

# HISTORY – 5-HMF Technology

Autoclaves

**2011**

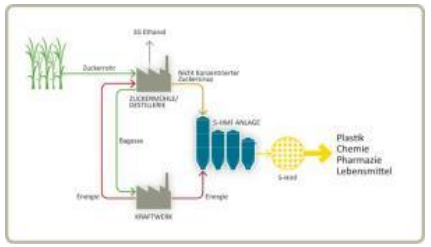
KIT Test-Installation

EU Project: BioConSepT

**2012**

AVA Biochem
Plant Construction

**2013**




Scale-up
HMF-FDCA-plant

**Future**

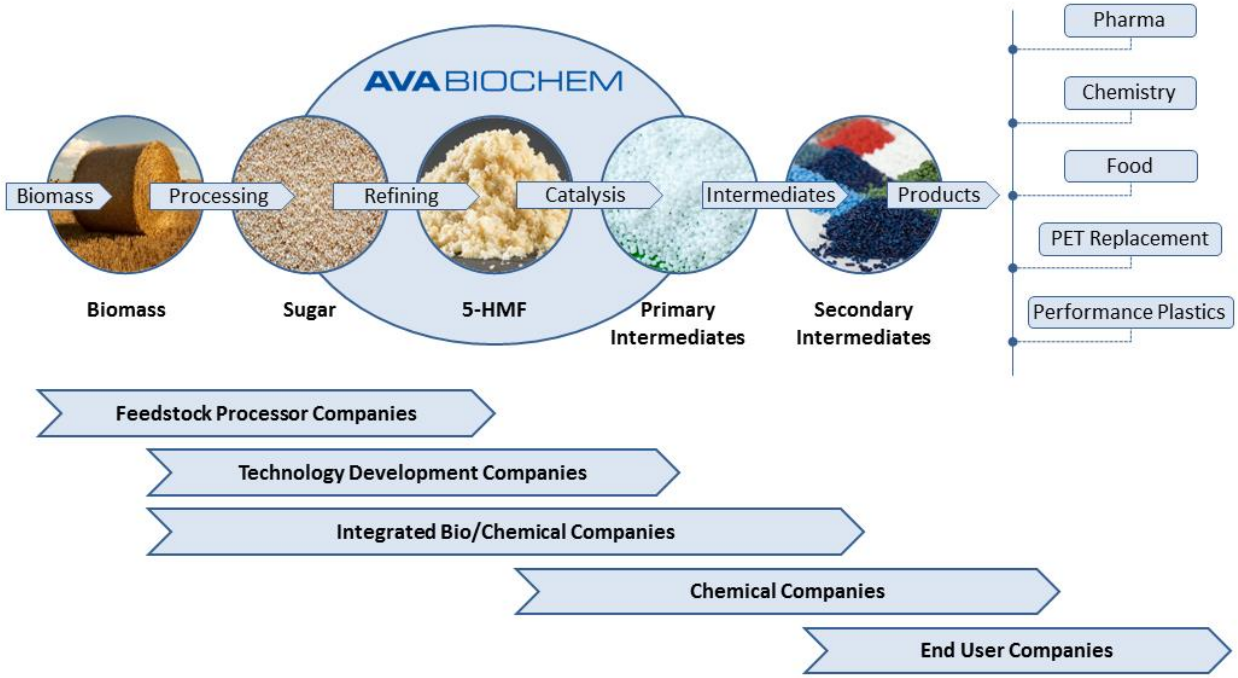
**12.2011**

Founding
AVA Biochem
Muttenz, Switzerland

**01.2014**

AVA Biochem BSL AG
Start of 5-HMF Production, 20 t/y crystals or 300 t/y in water

# 5-HMF VALUE CHAIN

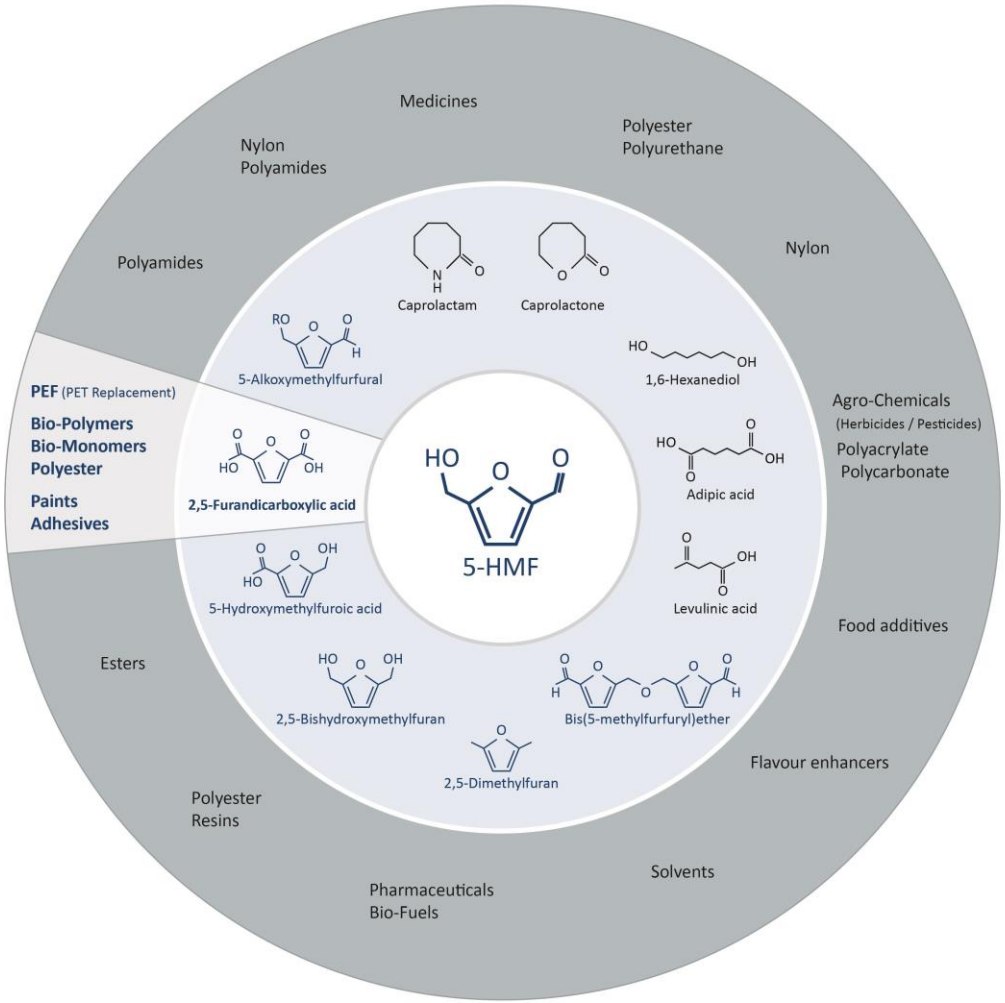



## AVA Biochem opens the door to sustainability & new bio-based materials

# WORLDWIDE FIRST DEDICATED 5-HMF PRODUCTION SITE

- Biochem-1 plant operated by AVA Biochem since January 2014
- Processing reliable, high quality 5-HMF
- Continuous hydrothermal process (high pressure chemistry) → not fermentation nor catalysis
- Process takes place in aqueous solution!
- Fully scalable technology: bulk production within reach


# 5-HMF - PERFORMANCE ADVANTAGES



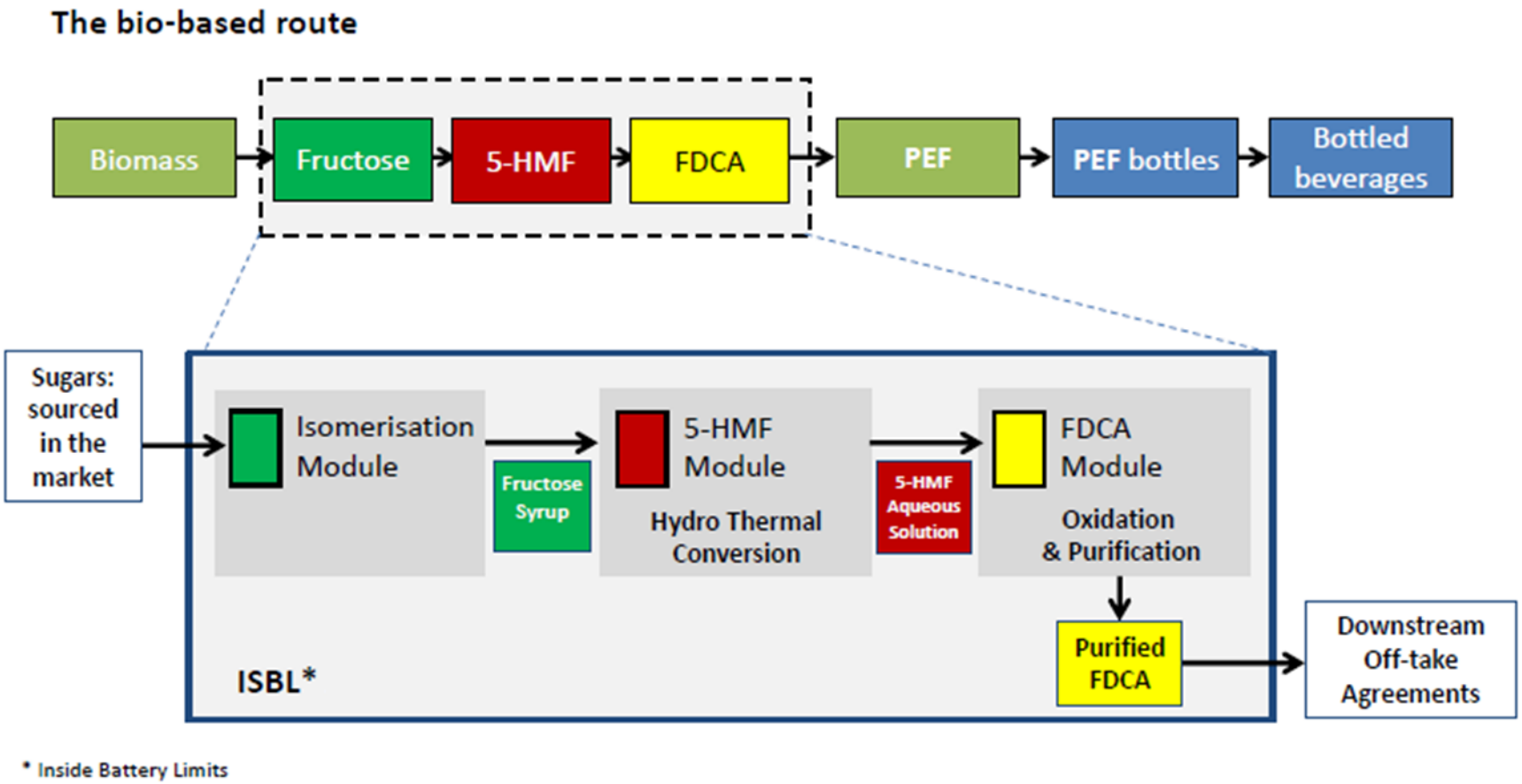

5-HMF is the starting point for many future bio-based products.

- used as performance ingredient in food, agro, pharma
- converted to at least 150 relevant chemicals
- converted to monomers for at least 20 different polymers → e.g. PEF
- used to replace formaldehyde in furniture production

# PEF - PERFORMANCE ADVANTAGES

| Performance | PEF | PET |
|---|---|---|
| Gas permeability 02 | 6-10 x better than PET | |
| Gas permeability CO2 | 2-5 x better than PET | |
| Moisture resistance H20 | 2 x better than PET | |
| CO2-Footprint | 50% better than PET | |
| Glass transition temperature TG | 84-90° C | 67-81° C |
| Melting point Tm | 195-265° C (stable up to 325° C | 250-270° C |
| Density | 1.43 g/cm3 | 1.36 g/cm3 |
| Young's modulus E | 3.0-3.5 GPa | 2.1-3.1 GPa |
| Field strength | 90-100 MPa | 50-60 MPa |

# LARGE SCALE PRODUCTION PLANT




* Inside Battery Limits

# OPTION 1: «SUGAR-CO» – BIO-REFINERY WITH SUGAR CO-LOCATION

Driver: AVA-CO2 & Biomass Partners

Driver: B2C Market Driver

## SCOPE of LARGE SCALE PRODUCTION PLANT

(30'000 to 120'000 t/y per production site)

**Biomass**

Sugar Cane

Wood

Corn

Sugar beet

Others…

Sugar → Fructose → AVA BIOCHEM 5-HMF "Solution Provider"

→ Resins
→ FDCA
→ DHMF
→ Others

## Polymeri-sation

*Downstream*

Resins → Duro-plastics

FDCA → PEF

DHMF → Others

## SCOPE of PRODUCT DEVELOPMENT

| | | | |
|---|---|---|---|
| Boards | … | … | Furniture |
| … | … | … | others |
| … | … | … | Bottles |
| … | … | … | Films |
| … | … | … | Yarns |
| … | … | … | others |

# OPTION 2: «CHEM-CO» – BIO-REFINERY WITH CHEMICAL CO-LOCATION

Sugar-Market

Driver: AVA-CO2 & Chemical Partner

Driver: B2C Market Driver

**Biomass**
Sugar Cane

Wood

Corn

Sugar beet

Others…

Sugar

**SCOPE of LARGE SCALE PRODUCTION PLANT**

(30'000 to 1200'000 t/y per production site)

Fructose

Glucose

AVA BIOCHEM

5-HMF "Solution Provider"

Monomers

Monomers

Chemicals

Chemicals

**Polymeri-sation**

*Downstream*

PEF
PET
Nylon
Resins
Duroplastics
…

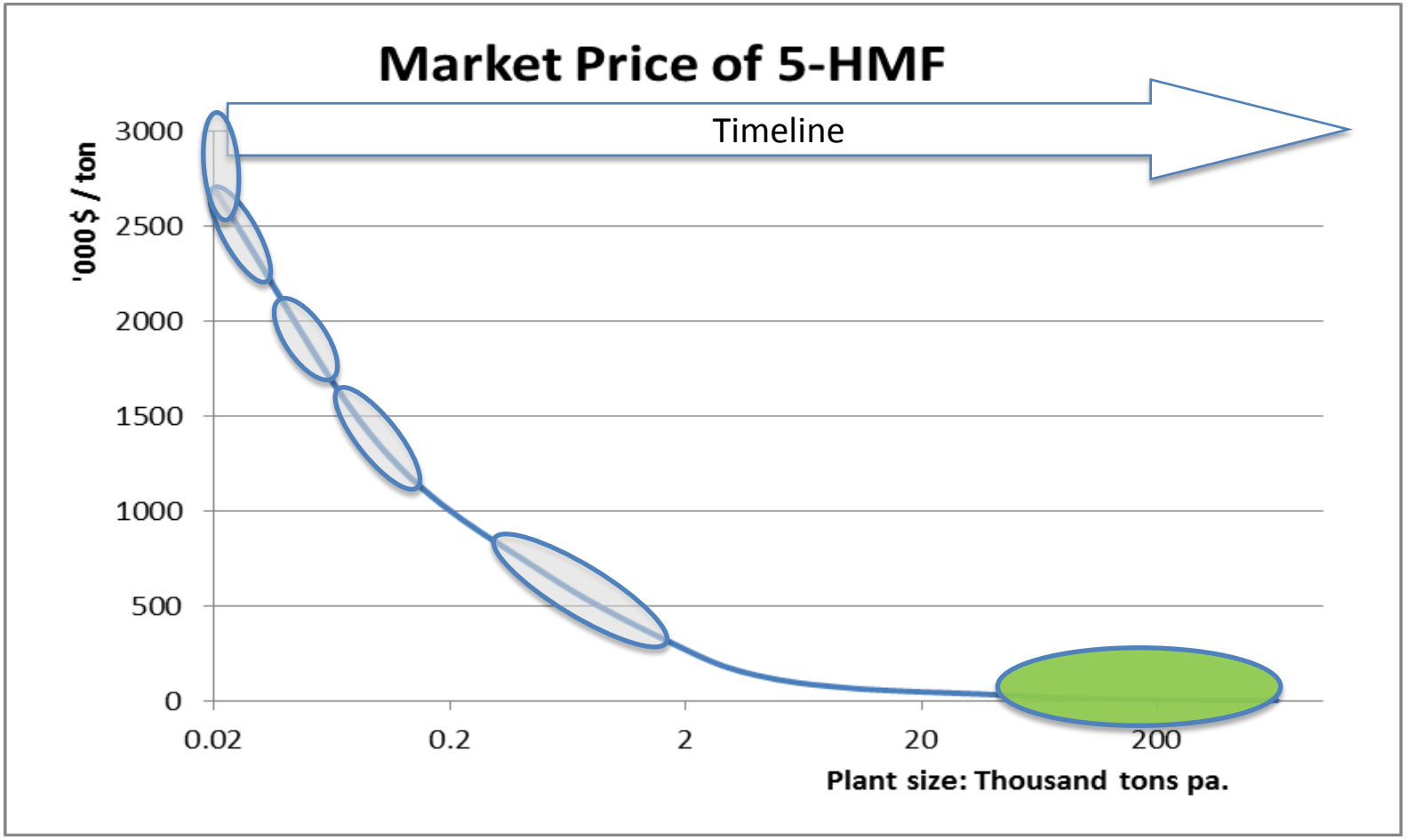
**More than 150 Bulk, Special and Fine Chemicals**

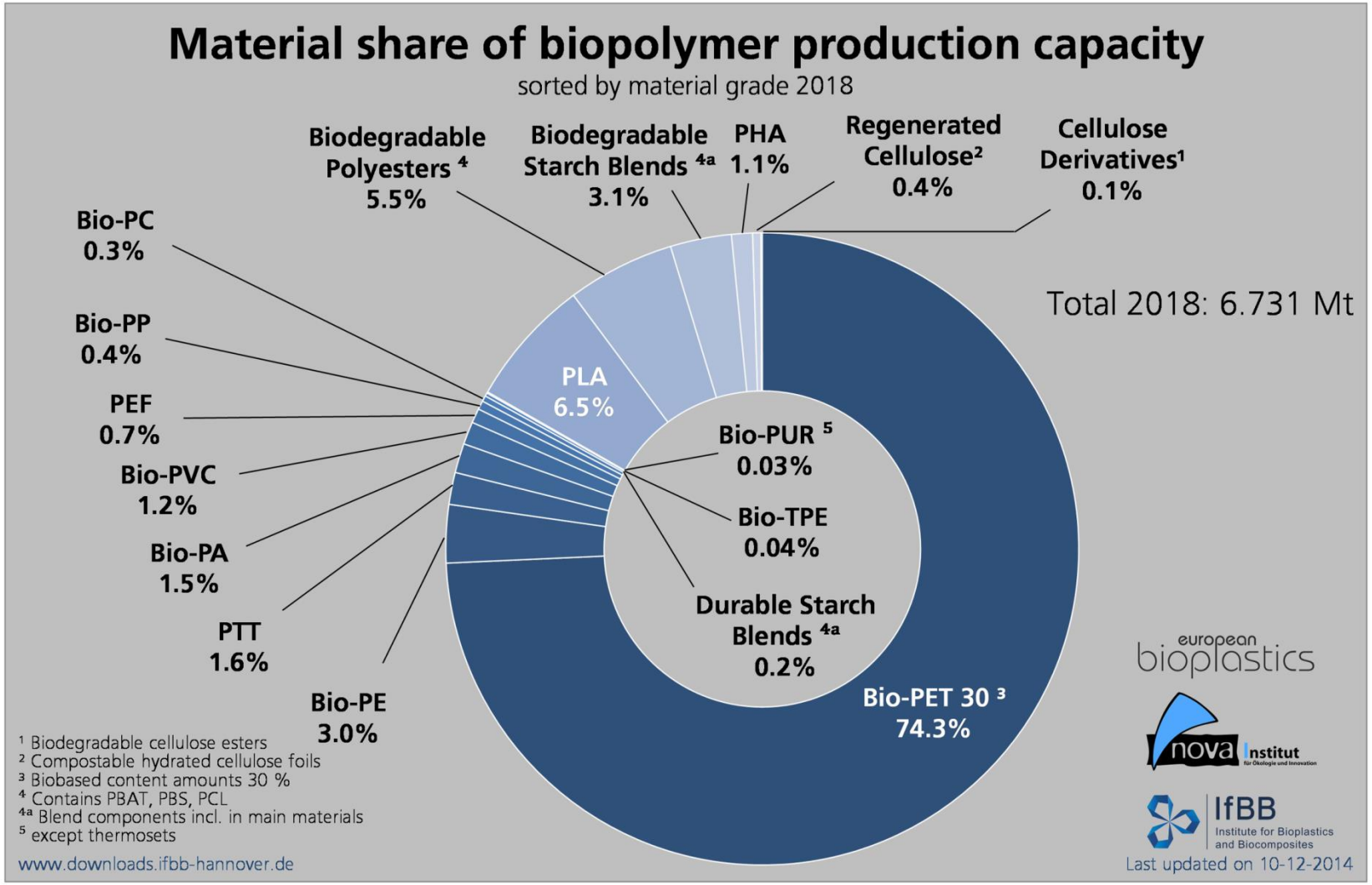
*Downstream*

**SCOPE of PRODUCT DEVELOPMENT**

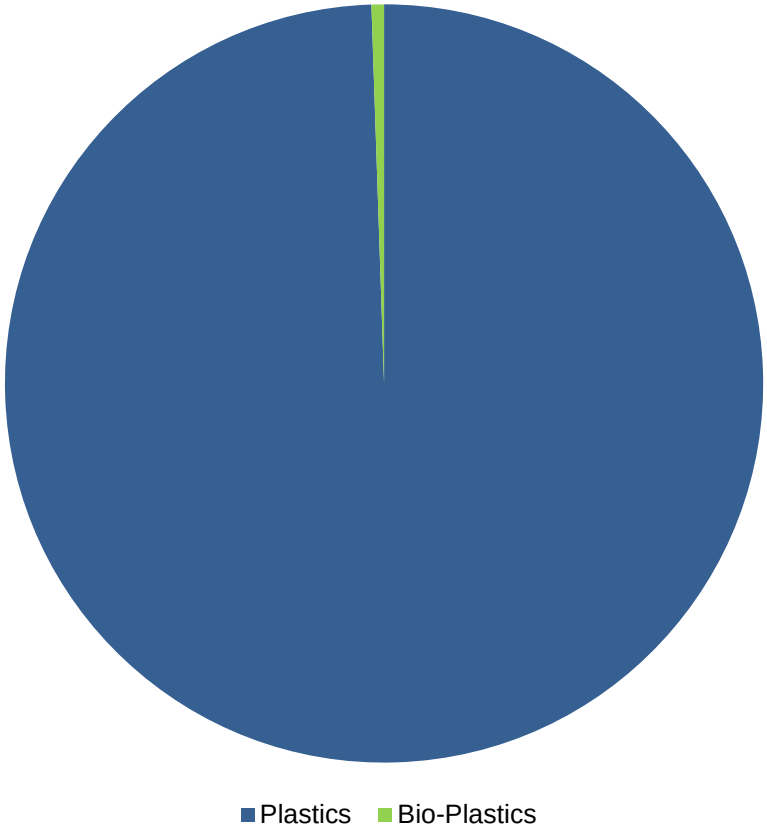
| | | | |
|---|---|---|---|
| … | … | … | Bottles |
| Boards | … | … | Furniture |
| … | … | … | Films |
| … | … | … | Yarns |
| … | … | … | others |

# MARKET PRICE DEVELOPMENT 5-HMF




Material share of biopolymer production capacity
sorted by material grade 2018
Biodegradable Polyesters 4 5.5%
Biodegradable Starch Blends 4a 3.1%
PHA 1.1%
Regenerated Cellulose2 0.4%
Cellulose Derivatives1 0.1%
Bio-PC 0.3%
Bio-PP 0.4%
PEF 0.7%
Bio-PVC 1.2%
Bio-PA 1.5%
PTT 1.6%
Bio-PE 3.0%
PLA 6.5%
Bio-PUR 5 0.03%
Bio-TPE 0.04%
Durable Starch Blends 4a 0.2%
Bio-PET 30 3 74.3%
Total 2018: 6.731 Mt
1 Biodegradable cellulose esters
2 Compostable hydrated cellulose foils
3 Biobased content amounts 30 %
4 Contains PBAT, PBS, PCL
4a Blend components incl. in main materials
5 except thermosets
www.downloads.ifbb-hannover.de
european bioplastics
nova Institut
IfBB Institute for Bioplastics and Biocomposites
Last updated on 10-12-2014

# BIO-PLASTICS INDUSTRY IS STILL IN ITS EARLY STAGES




Plastics: 299 Mio. t/a

Bio-Plastics: 1.6 Mio. t/a

Source: worldwatch institute / european bioplastics (2013)

**If you are looking for 5-HMF based products and solutions like PEF plastics you should talk to us**

- ✓ 5-HMF is available for research, development and special applications
- ✓ Proven, innovative technology
- ✓ Scalable to match growing market demand
- ✓ Potential high demand from growing bio-based packaging market
- ✓ Many other lucrative segments such as formaldehyde replacement
- ✓ Promising applications in Food, Pharma, Agro, etc.
- ✓ Open Innovation approach to collaborate with partners from the value chain

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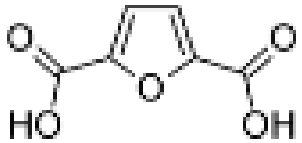
# THE FUTURE OF PLASTICS IS BIO-BASED

## Replacement of Formaldehyde in Duroplastics, Thermoplastics and Elastomers

| | |
|---|---|
| **5-HMF + Phenol** | **→ Phenoplasts** |
| **5-HMF + Urea**<br>**Thiourea**<br>**Melamin**<br>**Cyanamide**<br>**Dicyanamide**<br>**Diaminohexane**<br>**Polyamines** | **→ Aminoplasts** |
| **5-HMF + Polyisocyanates** | **→ Polyurethanes** |
| **5-HMF + Butanone**<br>**p-Toluenesulfonamide** | **→ Thermoresistant resins** |

# Pathways from 5-HMF to Polymers containing a Furan-Ring

**Furandicarboxylic acid**
**FDCA**




→ **Polyesters**
→ **PEF (Polyethylenefuranoate)**
→ **PBF (Polybutylenefuranoate)**
→ **Polycarbonates**
→ **PBAF (replacing PBAT)**

http://www.grandviewresearch.com/industry-analysis/fdca-industry

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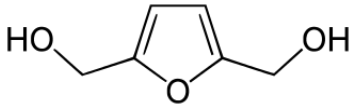
**2,5-Bis(hydroxymethyl)furan**
**DHMF**




→ **Polyesters**
→ **Polyurethanes**

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**5-Hydroxymethyl-furan-2-carboxylic acid**
**HFCA**

→ **Polyester**

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**2,5-Bishydroxymethyltetrahydrofurane**

→ **Polyesters**
→ **Polyurethanes**

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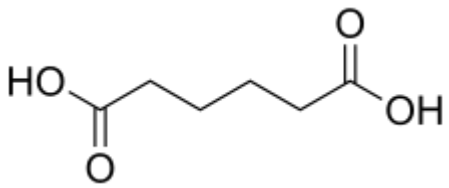
**2,5-Bis(aminomethyl)furan**

→ **Polyurethanes**

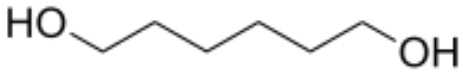
## Polymers containing C6 Chains

**Adipic acid**



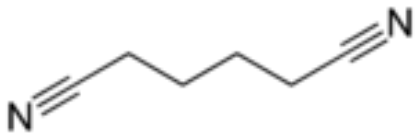

→ **Polyamide 46, 66, …**
→ **Polyurethan**
→ **Polyester**
→ **Polyesterpolyol**

**1,6-Hexanediol**



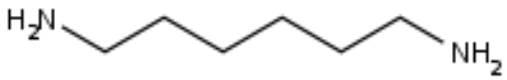

→ **Polyester**
→ **Resins**

**Adiponitrile**




→ **Polyamides**

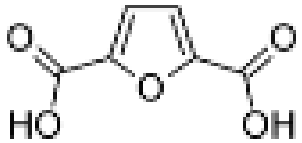
**1,6-Diaminohexane**




→ **Polyamide 66, Nylon 6-6**

# Polymers without Furan-Ring or C6-Chains

**Furandicarboxylic acid**




→ **Polycarbonates**

http://www.grandviewresearch.com/industry-analysis/fdca-industry

**Replacing Bisphenol A**

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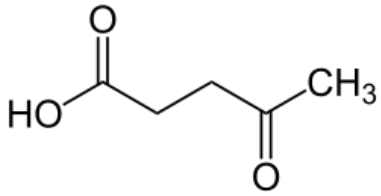
**Levulinic acid**




→ **Polyacrylate**

→ **Polycarbonate**

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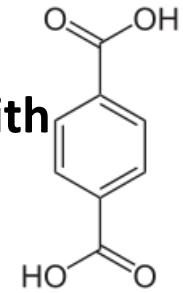
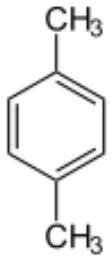
**Terephthalic acid, p-Xylene**

**with**




→ **PET, Polyethylenetherephthalate via Diels-Alder-reaction ethylene**