Furanics:
versatile molecules applicable for biopolymers applications

Ed de Jong

Avantium Technologies BV, Zekeringstraat 29,
1014 BV Amsterdam, The Netherlands
E-mail address: ed.dejong@avantium.com

Outline of the presentation

- Why novel Biopolymers & Biofuels
- Avantium's approach
- Furanics as starting material for polyesters
- Key elements & learning points
- Conclusions

The ideal Biopolymer & Process

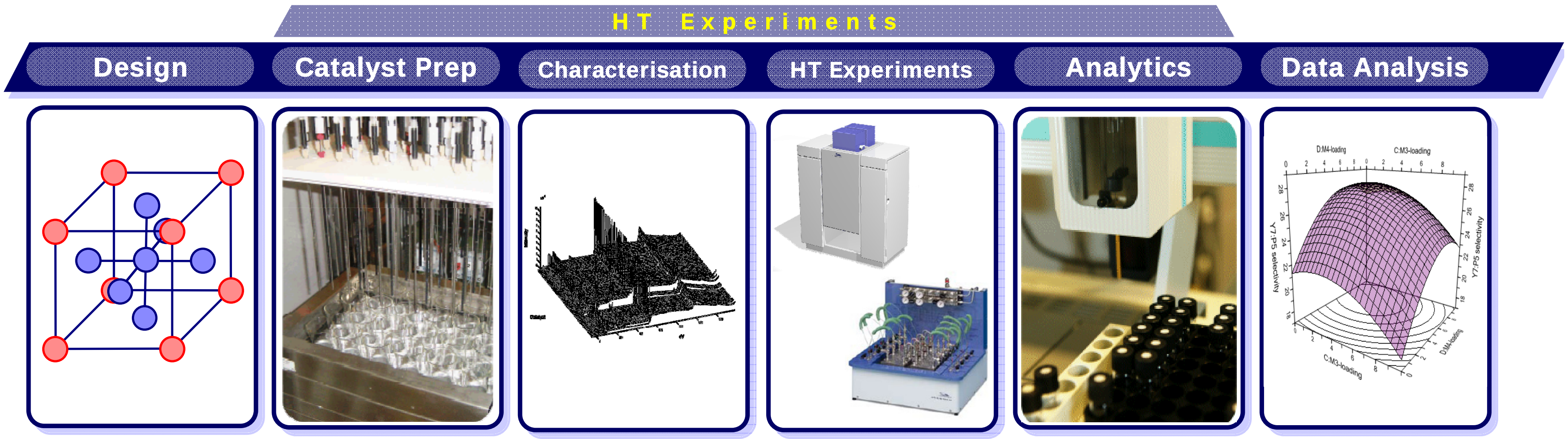
- Big market
- Comparable characteristics with commodity plastics
  - T*g*
  - Molecular Mass
  - Transparency
  - Color
- Low raw material and production costs
- Proven technologies
  - Monomer production
  - Polymer processing
- High efficiency route
- Integration with current refineries

Avantium's approach

- Cheap & abundant renewable feedstocks: carbohydrates
  - Both C5 and C6 sugars
- Use of platform chemicals: furanics
- Discovery, screening and optimization by application of High Throughput Methodologies
- Catalytic, fixed bed process
- Partnering up- and downstream

HTT Methodology

AVANTIUM



HTT is about the Methodology – Not just technology:

IT IS THE COMPLETE WORK FLOW

Not just conventional experimentation faster

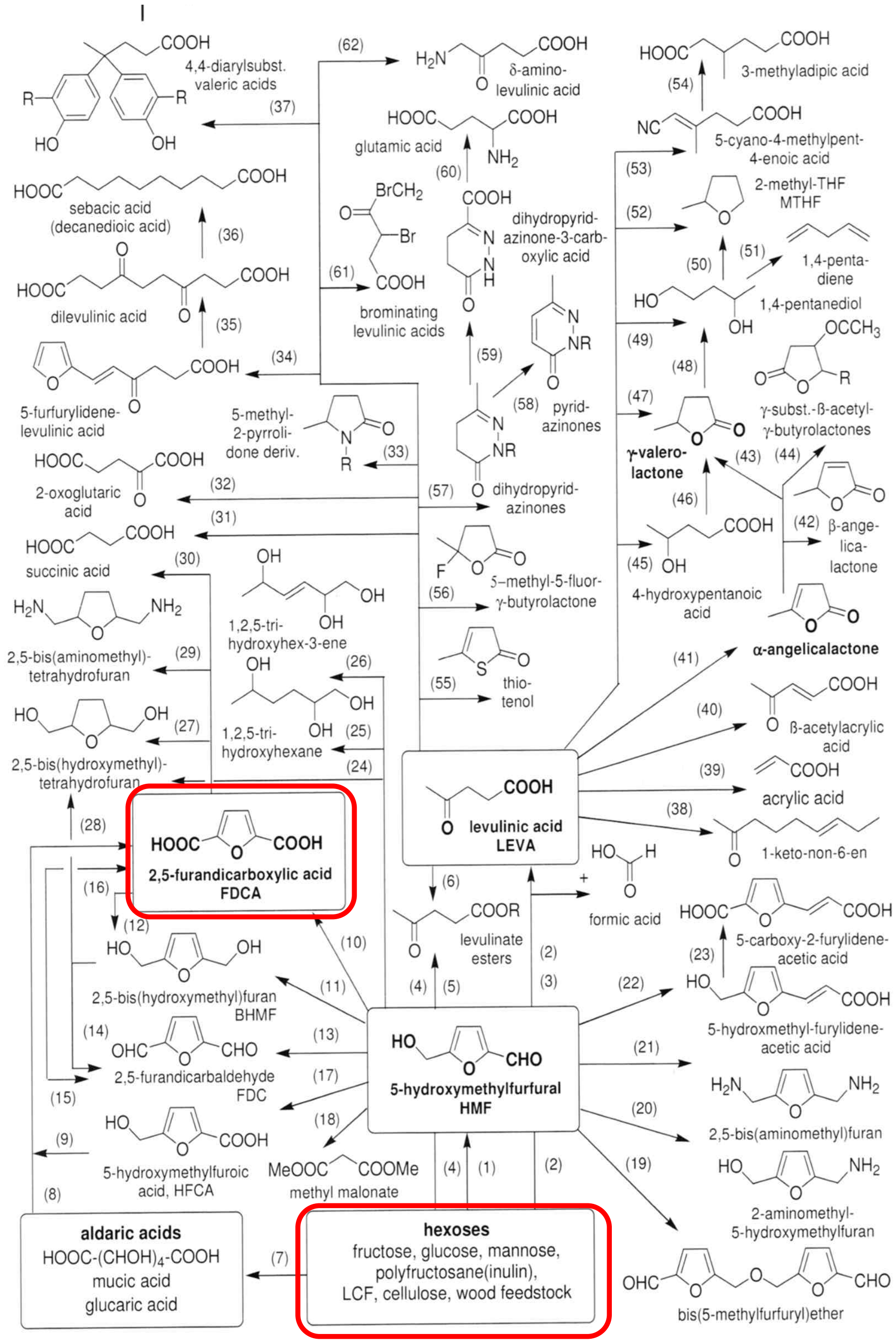
Working in new ways

Expanding the parameter space

Renewable Raw Materials

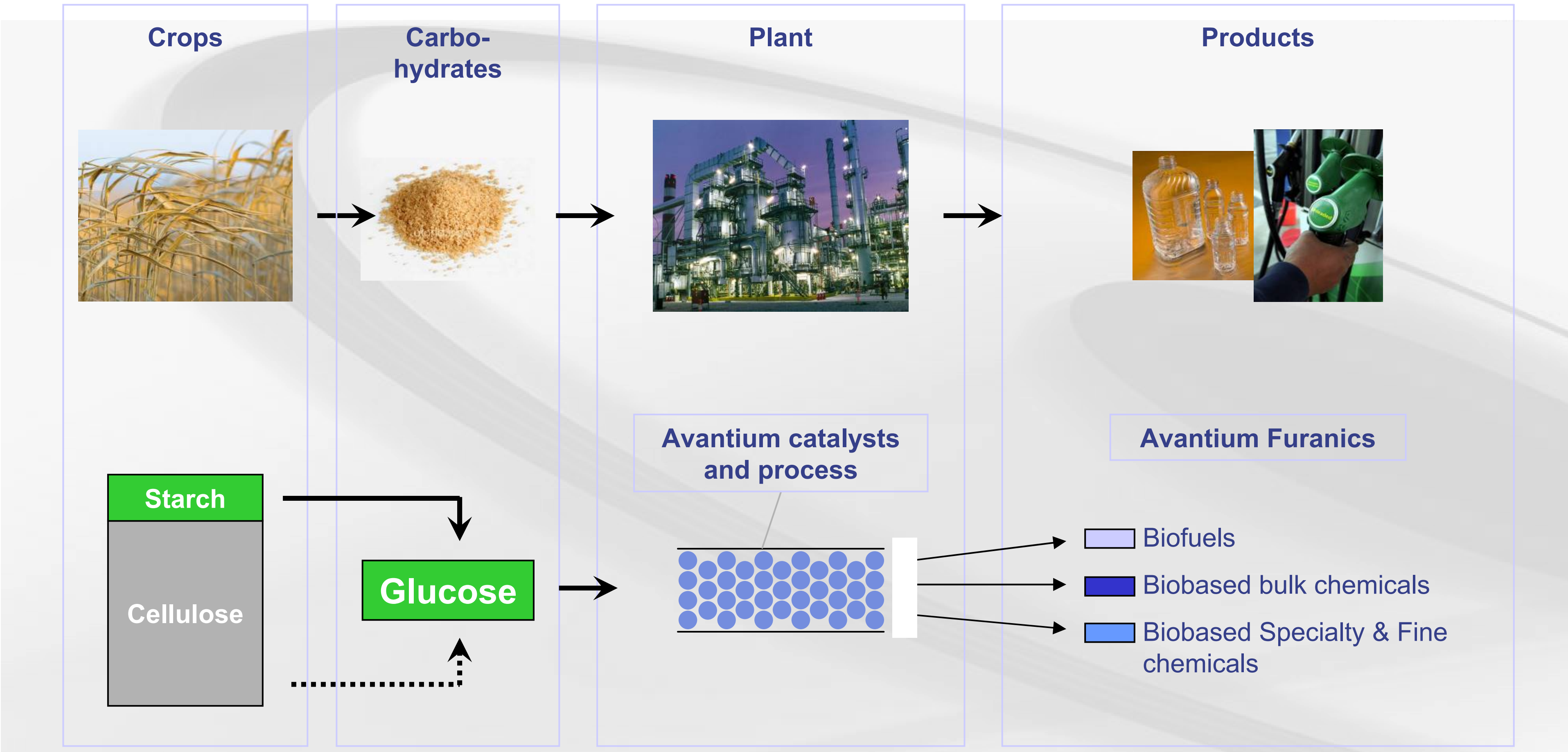
- Carbohydrates are excellent starting materials for the production bulk and specilaty-chemicals
- Intelligent usage of the intrinsic functionality already present in carbohydrates
- Furanics (HMF) identified as high potential starting material

Source: Gruber, Biorefineries, Wiley 2006



Avantium's Approach to Catalytic Biomass Conversion

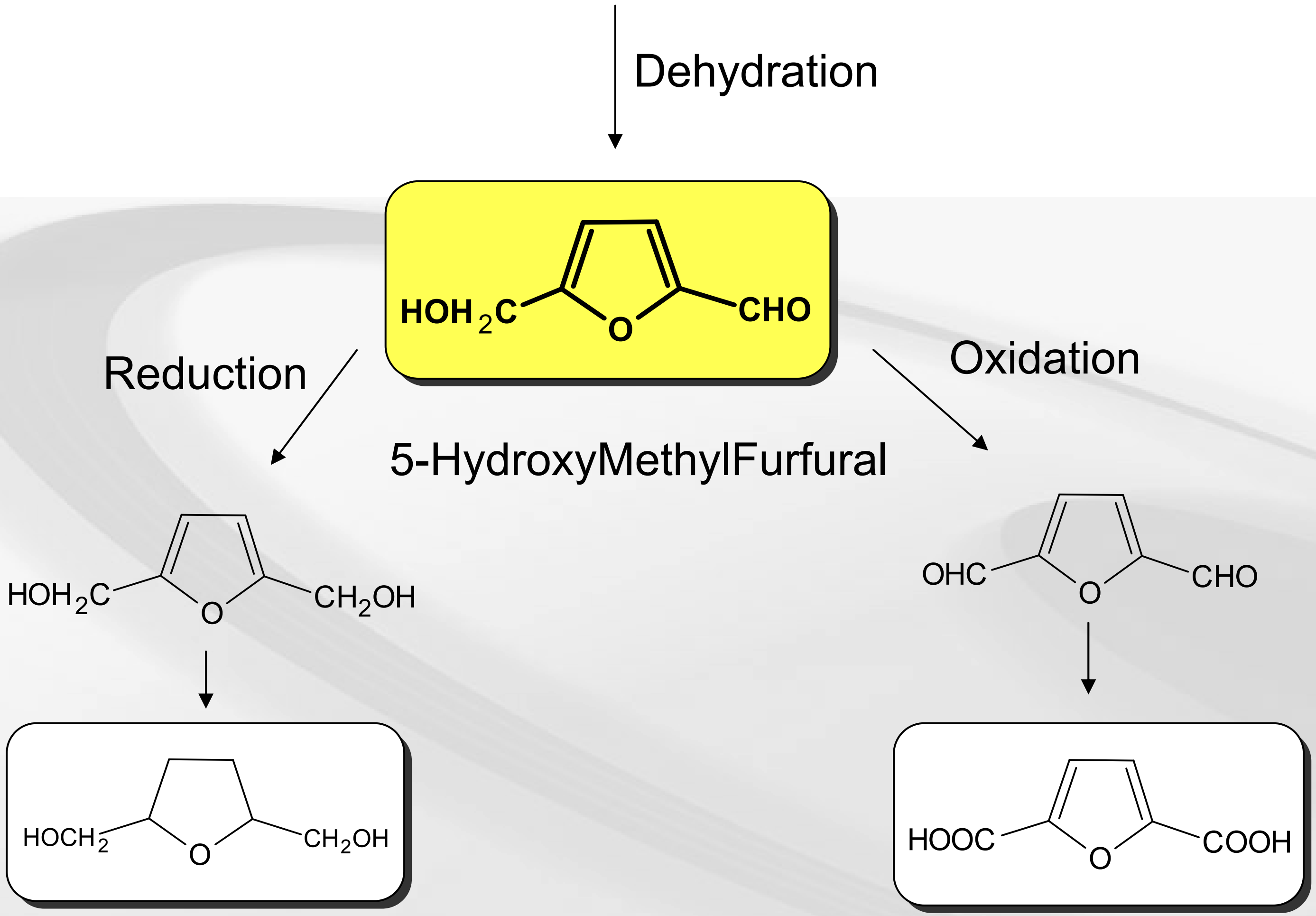
Unlocking the potential of a new class of biofuels: Furanics



Biopolymers from Furan-based Monomers

Potential Monomers

Sugars (Fructose, Glucose)

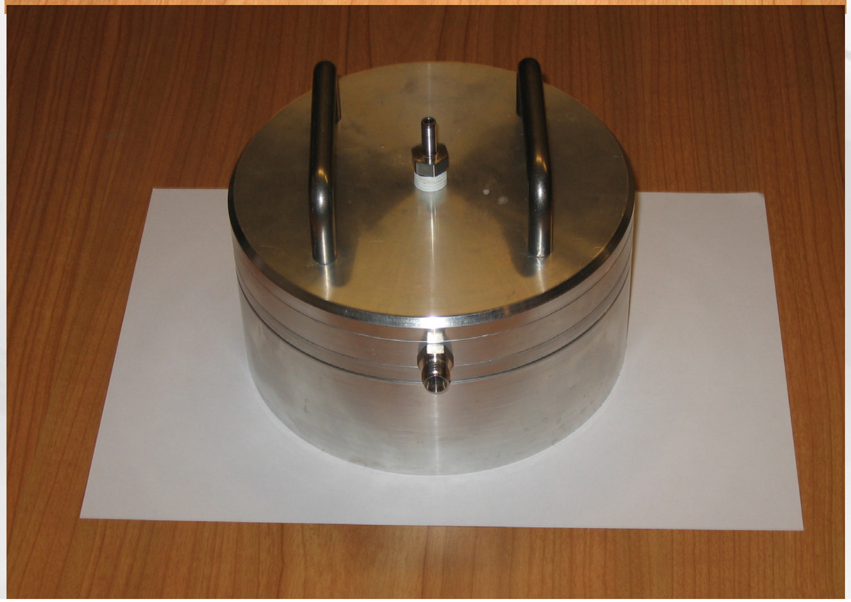


2,5-Hydroxymethyl Tetrahydrofuran

2,5-FuranDiCarboxylic Acid

Target Polymers from FDCA

- Polyesters
- Polyamides
- Copolymers



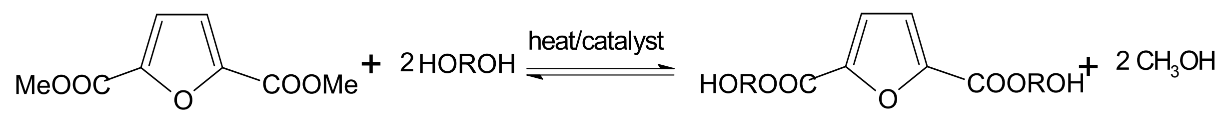
Dimethyl 2,5-Furandicarboxylate

DM-FDCA

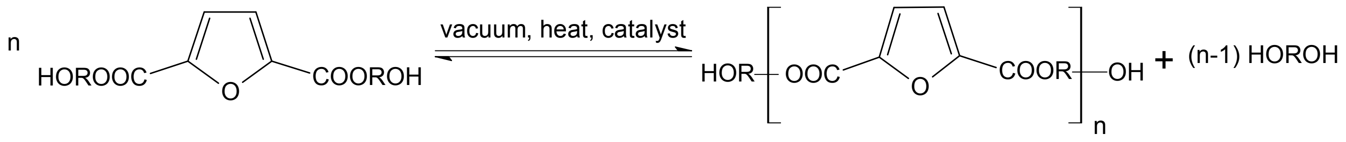
As Monomer in Polyester Synthesis

Polyester Synthesis

Transesterification



Polycondensation



Production of Polyesters in Film Reactor

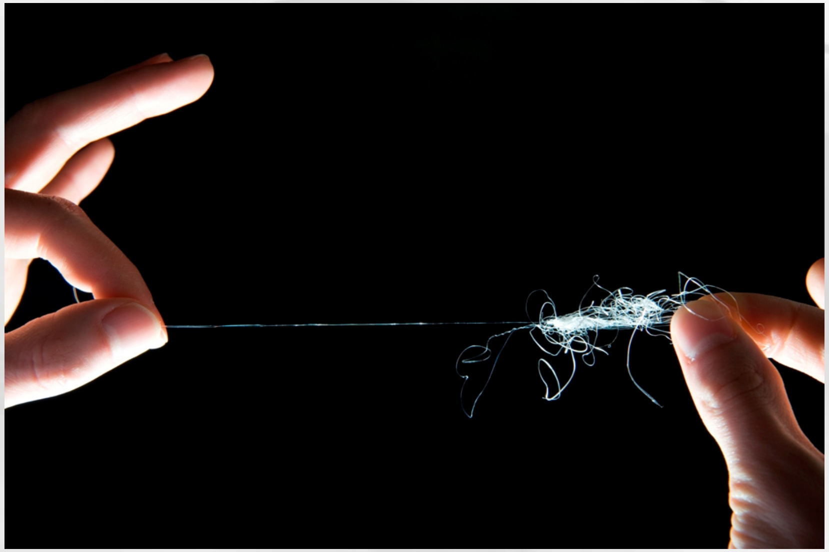
Establish appropriate conditions in reactor

High molecular weight, Low coloration

Parameters to change

- Catalyst – catalyst mixtures
- Catalyst concentration
- Temperature
- Reaction time

Production in larger scale



Thermal Properties of FDCA based polyesters

Diol	M_w	PD	$T_g(^oC)$	$T_m(^oC)$	$T_{cryst}(^oC)$	TG	
						$T_{start}(^oC)$	$T_{inf}(^oC)$
Ethylene glycol	52000	2.81	86.2	211.4	160.3	312	394
1,3-propanediol	59300	2.57	56.9	171.9	140.0	312	392
2,2-dimethyl-1,3-propanediol	36000	2.28	67.5	199.6	143.3	294	408
1,4-butanediol	59100	2.52	44.5	171.5	115.3	286	388
Cis-2-butene-1,4-diol	11800	2.95	47.8	164.3	113.0	264	330, 341
1,6-hexanediol	53500	2.35	13.2	144.5	116.3	292	390
3-hexene-1,6-diol	37500	2.67	23.3	126.7	78.4	278	354
1,4-bis(hydroxymethyl) cyclohexane	33600	2.33	102	271	229	319	396

T_{start} = starting point of decomposition

T_{inf} = inflection point of TG curve

T_{crist} = crystallization temperature

Outline of the presentation

- Why novel Biopolymers & Biofuels
- Avantium's approach
- Furanics as starting material for polyesters
- Conclusions & Future Steps

Conclusions:

Key elements & learning points

- High throughput methodologies necessary to accelerate process and product development
- Multidisciplinary and knowledgeable team essential
- Involvement of raw material suppliers in early stage
- Availability of large quantities necessary for testing
- Parallel process and application studies
- Involvement of application developers and end users for process and application know-how & future developments
- Early assessment of necessary product characteristics
- Early assessment of economics and consequent essential elements of process

Our Amazon Program in a Nut Shell

2009 - 2010 Time Frame

Feedstock

Crops

C_5 / C_6 sugars

Process

Conversion

Lab-pilot

Pilot

Testing

Properties

Material properties

Engine test

Application Development

Plastics

Fuels

CONFIDENTIAL