A NEW WAVE IN BIO-BASED MATERIALS

De-bottlenecking biorefineries & creating maximum value for biomass
WHY?
We have a tremendous amount of oil based materials and products in our lives.
We have a tremendous amount of oil based materials and products in our lives.
These we can already bring back to you as bio-based products:
These we can already bring back to you as bio-based products:

Lignin-based resins and adhesives, wood-fibre composites
These we can already bring back to you as bio-based products:

See? That’s everything!
## Waste:

<table>
<thead>
<tr>
<th></th>
<th>Oil</th>
<th>Renewable materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material variability</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Yield-to-products</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Adds Carbon to the system</td>
<td>Low</td>
<td>Has high potential to capture carbon</td>
</tr>
<tr>
<td>Carbon capture</td>
<td>Low</td>
<td>Has high potential for recycle or degradation</td>
</tr>
<tr>
<td>End-of-life</td>
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</table>

- **Oil**
  - Low raw material variability
  - High yield-to-products
  - Adds Carbon to the system
  - Cumulates to environment

- **Renewable materials**
  - High raw material variability
  - Low yield-to-products
  - Has high potential to capture carbon
  - Has high potential for recycle or degradation
We need to find NEW SOLUTIONS.
**Vocabulary**

**BIOREFINERY**

The coproduction of a range of biologically-based products (food, feed, materials, chemicals) and energy (fuels, power, heat) from biomass.

**LIGNOCELLULOSIC**

Lignocellulose refers to plant dry matter (biomass), so called lignocellulosic biomass. It is the most abundantly available raw material on the Earth for the production of renewable fuels, chemicals and materials. It is composed of carbohydrate polymers (cellulose, hemicellulose), and an aromatic polymer (lignin).
THE BIG PICTURE: HAVE A BIOREFINERY AND MAKE IT WORK

1. FEED STOCK COSTS
2. PRE TREATMENT EFFICIENCY
3. RIGHT ENZYME
4. TOO MANY SIDE STREAMS
5. TOO FEW PRODUCTS
6. TOO LOW VALORIZATION
7. CONNECTION TO MARKET
FEEDSTOCK COSTS

Selection of material

Location

Market supply and demand

Regulation

Technologies

Sustainability
You do not want to replace all plastic with one feedstock. It’s not sustainable."
PRE TREATMENT EFFICIENCY

PULP
- 60% waste
- 40% pulp

AVERAGE BIOREFINERY
- 50% dirty lignin
- 50% dirty sugars

ZERO WASTE
- 30% lignin
- 30% hemicellulose
- 40% cellulose
Enzyme technologies can be integrated part of the refinery concept – we have just the model for you!”
Enzymatic technologies work seamlessly with chemical and mechanical solutions creating a full value chain.
FINDING THE RIGHT ENZYME IS LIKE MIXING YOUR OWN SPICES
**BENEFIT OF TAILORED HYDROLYSIS ENZYMES**

Every substrate can be addressed with multitude of enzymes, and a failure to find an optimal one leads to overdosing, low process yields, increased waste volumes and – what is worst – loss of money.

MetGen’s production strains and processes together with the flexible business model allow for licensing and on-site manufacturing options.

Collaboration with other players in the value-chain lowers the technology costs even further.
COST OF ENZYME / TON OF BIOMASS

COST PROJECTION FOR HYDROLYSIS ENZYMES FOR >90% SUGAR YIELD FOR AN ASIAN BIOREFINERY PROJECT
Biomass is not oil – it’s a soup of the day."
4  

TOO MANY SIDESTREAMS AND TOO MUCH WASTE.

One-product-in-one-product-out is outdated and wasteful model.

Waste is expensive!

Traditional process uses 40.

We can extend this to 95 %

GOAL IS ZERO-WASTE
These things are not complicated, they are very black and white."
5

TOO LOW VALORIZATION

Biomass to landfill → Clean Sugars and lignin
Sugar to fuel → Platform chemicals and materials
Lignin to burn → Materials and chemicals

HOW TO DO THIS?
STREAMLINED CHEMO-ENZYMATIC ROUTE TO BIOPLASTICS AND PLATFORM CHEMICALS

**2nd Gen Glucose**

**BIO-CONVERSION**
- MetZyme® PURECO™
- 55% - 100% Conversion

**Fructose Glucosone**

**BIO / CHEMICAL CONVERSIONS**
- Dehydration
- Oxidation
- HMFO
- Heterogeneous catalysts

**Platform Chemicals**

**MetGen’s patent-filed processes enable:**
- Complete C6 conversion
- Use of 2nd Gen sugars
- Streamlined processes and higher yields
- New routes to platform chemicals
ENZYMATIC SOLUTIONS FOR FIBRE MODIFICATION

Nanocellulose & MFC

Grafting and surface charge

Textiles

Recycling
"You don’t make sneakers, loudspeakers or dashboards out of crude oil. You use refined fractions."
ENZYMATIC LIGNIN VALORIZATION WITH METNIN™ TECHNOLOGY

Degree of Functionalization:
- Low
- Medium
- High

Temperature [°C]:
- 1000
- 900
- 800
- 700
- 600
- 500
- 400
- 300
- 200
- 100

Processes:
- METNIN™
- Chemical Oxidation
- Pyrolysis
- Hydrolysis/Solvolyis
- Gasification
- Hydrogenolysis
ENZYMATIC LIGNIN FRACTIONING PROCESS

BIOREFINERY LIGNIN

Solubilization

Water NaOH Mixing Heating

Solids separation

85%

INSOLUBLE FRACTION

15%

ENZYME + Water NaOH Mixing Aeration

Enzymatic Fractionation

METNIN™ ULTRA: Various fractions of MEDIUM MW 30-50%

METNIN™ NANO: LOW MW 25-55%

UF 70KDA

UF 10kDA

UF 3kDA

NF
ENZYMATIC LIGNIN FRACTIONING PROCESS

BIOREFINERY LIGNIN FROM FILTER PRESS

Solubilization

Water
NaOH
Mixing
Heating

ENSEMBLY
LIGNIN
FROM FILTER PRESS

ENZYME + Water NaOH Mixing Aeration

Enzymatic Refining

Solids separation

INSOLUBLE

99%

1%

UF 1

UFs 2-4

NFs 1-2

METNIN FRACTIONS @ 20% DS:

MICRO: HIGH MW 6-9 kDa 20-60%

METNIN ULTRA: MEDIUM MW 1-3 kDa 30-50%

METNIN NANO: LOW MW <1 kDa 25-55%

TO DOWNSTREAM PROCESSING & FORMULATION
See next slide for options

Chemicals back to solubilization & Enzymatic Refining

Process water for diafiltration of the fractions at all the membrane steps

UFs 2-4

NFs 1-2

RO
POTENTIAL DOWNSTREAM PROCESSING ROUTES

METNIN FRACTIONS FROM MEMBRANE FRACTIONATION

MICRO: HIGH MW
5 – 10 kDa

- EVAPORATION
  - LIQUID FORMULATION
    - Water soluble RESIN

- DRYING
  - powder RESIN
  - COMPOSITES

METNIN ULTRA: MEDIUM MW
1 – 3 kDa

- ACID PRECIPITATION
  - LIQUID FORMULATION
    - METNIN™ SHIELD (sizing product)

- SOLIDS SEPARATION
  - SOLIDS SEPARATION
  - DRYING

METNIN NANO: LOW MW
< 1 kDa

- ACID PRECIPITATION
  - CO-PRECIPITATION
    - EVAPORATION

- SOLIDS SEPARATION
  - LIQUID FORMULATION

- DRYING
  - Water soluble RESIN

- DROPS-IN LIGNOPOLYOLS
  - POLYOLs, COMPOSITES, EMULSIFIERS, etc

THESE ARE CURRENT FOCUS AREAS

See next slide for unit ops
UNIT OPERATIONS

- Hold tanks for Metnin fractions
- DSP manifold
  - High-shear mixer
  - Liquid formulation tank
    - Liquid packing (IBC/Bulk containers)
    - Formulated liquid products e.g. Metnin Shield
- Steam evaporator
- Acid precipitation tank
- Co-precipitation tank
- Flash drying
  - Powder packing (silos/bulk bags)
  - Solid formulated products
- Steam evaporator
METNIN™ IMPACT ON LIGNIN

**FRACTIONATION**

- 10kDA retentate
- 3kDA retentate
- 3kDA permeate

**DEMETHYLATION**

- Normalized intensity (at 560 nm)

- Control
- METNIN™

**ACTIVATION**

- Total OH groups (mmol/g)
- Phenolic OH
- Aliphatic OH

Analysis provided by Prof. N. Labbé et al. Department of Forestry, University of Tennessee, USA.
TOO FEW PRODUCTS
6 TOO FEW PRODUCTS

Resins
Polymers
Barriers and coatings
# Enzymatic Lignin Refining Adds Value

<table>
<thead>
<tr>
<th>METGEN</th>
<th>Molecular Weight</th>
<th>Reactivity &amp; Solubility</th>
<th>Application</th>
<th>Bio-Equivalent Of</th>
<th>Price</th>
<th>Collaboration Partner Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currently Available Lignin</td>
<td>5–100 kDa</td>
<td>Poor</td>
<td>Fuel</td>
<td>Oil/ Electricity</td>
<td>50–100 €/ton</td>
<td>Fuel, thermoplastics, fillers</td>
</tr>
<tr>
<td>Enzyme Activated Lignin</td>
<td>METNIN MICRO 3–50 kDa</td>
<td>Medium</td>
<td>Resins &amp; Adhesives</td>
<td>Phenol From-aldehyde</td>
<td>400–500 €/ton</td>
<td>MDF, plywood, epoxy, and paint resins, carbon black</td>
</tr>
<tr>
<td>Enzyme Depolymerized Lignin</td>
<td>METNIN ULTRA 0.3–2 kDa</td>
<td>Good</td>
<td>Foams &amp; Composites</td>
<td>Polyols</td>
<td>1000–2000 €/ton</td>
<td>Insulation panels, flexible foams, furniture, construction material, car tires, barrier coatings</td>
</tr>
<tr>
<td>Enzyme Depolymerized Fractions</td>
<td>METNIN NANO 0.3 kDa 0.5 kDa 0.7 kDa</td>
<td>Excellent</td>
<td>New materials</td>
<td>Speciality Chemicals &amp; Polymers</td>
<td>&gt; 2000 €/ton</td>
<td>Coatings, Plasticizers, Cosmetics, carbon nanofibers, flavors, fragrances, detergents</td>
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FROM FOREST TO BRANDS – WHERE METNIN™ FITS?

NEW BIOREFINERIES
EXISTING PULP MILLS
WITH LIGNIN

LIGNIN MODIFICATION
w/ METNIN™

CHEMICAL & MATERIAL COMPANIES

BRANDS
e.g. Coca-Cola, IKEA, LEGO, Nike
BASIC ENGINEERING PACKAGE
INVESTMENT COST

- BUILDINGS: 1120 k€
- EQUIPMENT: 2780 k€
- OTHERS: 1950 k€

TOTAL INVESTMENT COST: 5850 k€

PLANT CAPACITY (feed):
7 kt DS/year

Precision of cost: +/- 20%
CASH FLOW

- OPERATING COST: -735 k€
- RAW MATERIAL COST: -2000 k€
- RAW MATERIAL UTILIZATION: 70%
- INCOME: 5390 k€
- PRODUCT PRICE: 1100 €/t DS

OPERATING DAYS

- 350 days/year

TOTAL INVESTMENT COST

- 5850 k€

PLANT CAPACITY (feed)

- 7 kt DS/year
INVESTMENT COST

PLANT CAPACITY

7 kt
DS/year

TOTAL INVESTMENT COST
5,85 M€

CASH FLOW
+2,55 M€/year

PLANT CAPACITY

50 kt
DS/year

TOTAL INVESTMENT COST
28 M€

CASH FLOW
+18,25 M€/year
“Valorization of lignin has a hell of an impact.”
Future of leadership is like conducting an orchestra where everyone plays their own instrument – with passion.”
Future of leadership is like conducting an orchestra where everyone plays their own instrument – with passion.

There is no reason to build a bridge unless you have a vision of the other side.

WE BUILD BRIDGES.

Open innovations
We know HOW to do this.
THE BIG PICTURE: HAVE A BIOREFINERY AND MAKE IT WORK

1. MORE VERSATILE, SUSTAINABLE AND AFFORDABLE FEEDSTOCKS.

2. & 3. TECHNOLOGIES AND ENZYMES ARE OPTIMIZED TOGETHER. ENZYMES ARE AFFORDABLE AND LOCALLY PRODUCED.

4. THERE ARE NO WASTE STREAMS.

5. & 6. NEW TECHNOLOGIES ENABLE NEW PRODUCTS AND HIGH VALORIZATION.

7. MARKETS HAVE EXPANDED AND THE SALES INCREASED.
“This is a true refinery, not a waste generator.”
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MetGen – the friendly enzyme company invites you to join in the bio-based industry revolution.